

# I-5 Corridor Reinforcement Project Draft Environmental Impact Statement

## Appendices G-I, K-N

November 2012



DOE/EIS-0436

Cooperating agencies: U.S. Army Corps of Engineers; Oregon Energy Facility Siting Council; Washington Energy Facility Site Evaluation Council; Cowlitz and Clark Counties, Washington



# **I-5 Corridor Reinforcement Project**

## **Draft Environmental Impact Statement**

### **Appendix G-I, K-N**

**Bonneville Power Administration**

**Cooperating Agencies:**

**U.S. Army Corps of Engineers, Oregon Energy Facility Siting Council,  
Washington Energy Facility Site Evaluation Council, Cowlitz and Clark Counties, Washington**

**November 2012**

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## **Appendix G**

### **Research on Extremely Low Frequency Electric and Magnetic Fields and Health**



*Health Sciences*

# Exponent<sup>®</sup>

**Research on Extremely Low  
Frequency Electric and  
Magnetic Fields and Health**



# **Research on Extremely Low Frequency Electric and Magnetic Fields and Health**

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January 2011

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## Acronyms and Abbreviations

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AC	Alternating current
ACGIH	American Conference of Governmental Industrial Hygienists
ALL	Acute lymphoblastic leukemia
AML	Acute myeloid leukemia
BNU	n-butylnitrosourea
BPA	Bonneville Power Administration
CI	Confidence interval
DMBA	7,12-dimethylbenz[a]anthracene
G	Gauss
ELF	Extremely low frequency
EMF	Electric and magnetic fields
EMI	Electromagnetic interference
ENU	ethylnitrosourea
EPRI	Electric Power Research Institute
HR	Hazard ratio
Hz	Hertz
IARC	International Agency for Research on Cancer
ICD	Implanted cardiac device
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IGF-1	Insulin-like growth factor 1
m	Meter
mG	Milligauss
MPD	Myeloproliferative disorder
NIEHS	National Institute of Environmental Health Sciences
NHL	Non-Hodgkin's lymphoma
NK	Natural killer
OR	Odds Ratio
ROW	Right-of-way
RR	Relative risk
SCENIHR	Scientific Committee on Emerging and Newly Identified Health Risks

SES	Socioeconomic status
SSI	Swedish Radiation Protection Authority
TWA	Time-weighted average
WHO	World Health Organization

## Introduction

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Electrical objects produce two field types—electric fields and magnetic fields. The term field is used to describe the way an object influences its surrounding area. A temperature field, for example, surrounds a warm object, such as a space heater or campfire. Electric and magnetic fields (EMF) surround any object that generates, transmits, or uses electricity, including appliances, electrical wiring, office equipment, generators, and any other electrical devices. These fields are invisible, and they cannot be felt or heard.

**Electric fields** occur as a result of the electric potential (i.e., voltage) on these objects, and **magnetic fields** occur as a result of current flow through these objects.<sup>1</sup> Just like a temperature field, both electric fields and magnetic fields can be measured, and their levels depend on the properties of the source of the field (e.g., voltage, current, and configuration) and the distance from the source of the field, among other things.

Both electric fields and magnetic fields decrease rapidly with distance from the source, such that a magnetic field of 300 milligauss (mG) within 6 inches of a vacuum cleaner diminishes to 1 mG at 4 feet (NIEHS, 2002). This is similar to the way that the heat generated by a space heater or a campfire lessens as a person moves farther away from it. Although ordinary objects do not block magnetic fields, objects such as trees and buildings easily block electric fields.

The electrical power system in the United States produces alternating current (AC) EMF that changes direction and intensity 60 times per second—i.e., a frequency of 60 Hertz (Hz).<sup>2</sup> This frequency is in the extremely low frequency (ELF) range of the electromagnetic spectrum. Electricity produced by generating stations flows as 60-Hz current through transmission and distribution lines and provides power to the many appliances and electrical devices that we use in our homes, schools, and workplaces. Magnetic fields are found throughout our environment

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<sup>1</sup> The electric field is expressed in measurement units of volts per meter (V/m) or kilovolts per meter (kV/m); 1 kilovolt per meter is equal to 1,000 V/m. The strength of magnetic fields is expressed as magnetic flux density in units called gauss (G), or in milligauss (mG), where 1 G is equal to 1,000 mG.

<sup>2</sup> Europe's electrical system produces 50-Hz EMF. Since 50-Hz EMF is also in the ELF range, research on 50-Hz EMF is relevant to questions on 60-Hz EMF.

because electricity is needed for so many things in our daily lives, from lighting, heating, and cooling our homes to powering our refrigerators and computers.

Questions about whether these ubiquitous exposures could affect our health began to be raised in the 1970s. Since then, researchers from many different scientific disciplines have investigated this question, and hundreds of studies have been conducted. The public frequently expresses concern about ELF EMF, particularly in the context of new transmission lines. The intent of this report is to describe what this large body of research has told us about ELF EMF and the precautions, if any, recommended by public health agencies

In July 2007, Exponent provided a report to the Bonneville Power Administration (BPA) that described the conclusions of a comprehensive, weight-of-evidence review published by the World Health Organization (WHO) in June 2007; the portion of Exponent's 2007 report that describes the conclusions of the WHO report is attached as Appendix 1 for reference.<sup>3</sup> The WHO review still represents the most recent comprehensive review of the literature by a multidisciplinary scientific panel. The WHO organized a multidisciplinary Task Group of 21 scientists from around the world to draft a Monograph that summarized the research and provided conclusions as to whether there are risks associated with ELF EMF and, if so, at what exposure levels (WHO, 2007a). The report concluded that the only established effects of ELF EMF exposure are acute neurostimulatory effects (i.e., shock-like effects) that occur at very high levels of exposure; these exposure levels are not encountered in ordinary residential or occupational environments. The fact sheet from the WHO review is attached as Appendix 2 (WHO, 2007b) and can be found at

<http://www.who.int/mediacentre/factsheets/fs322/en/print.html>.

Research is a constantly evolving process. Despite the volume of research available on ELF EMF and the large reduction in uncertainty that research has achieved over the years, scientists continue research in this area with the goal of clarifying and replicating old findings and testing new hypotheses. New studies on ELF EMF are published every month. While the WHO review provides a comprehensive and relatively up-to-date summary of the status of research on

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<sup>3</sup> Exponent. Assessment of Research Regarding EMF and Health and Environmental Effects. Olympic Peninsula Reinforcement Transmission Line Project. July 2007.

this topic, new research has the potential to modify or strengthen conclusions. The BPA has, therefore, requested an update on the research with regard to ELF EMF and health. This report provides an overview of the cumulative body of research published since the WHO review (January 1, 2006–October 1, 2010) and provides the reader with perspective on if, and how, recent research changes the WHO’s conclusions.

A summary of the methods scientists use to conduct studies and make decisions about health risks is included in Section 1 as a framework for understanding later discussions. In Section 2, the discussion of new research is broadly grouped by health outcome—cancer, reproductive effects, developmental effects, and neurodegenerative diseases. This discussion summarizes two types of research—epidemiology studies and experimental studies in animals (*in vivo*)—within each health outcome category. Experimental studies in cells and tissues (*in vitro*) of carcinogenesis are discussed briefly in Section 2. Other areas of research not reviewed by WHO are discussed in Section 3, including the possible effects of ELF EMF on the functioning of pacemakers, on flora and fauna, and on marine life. Finally, guidelines for ELF EMF exposure developed by scientific organizations to prevent against established health effects are summarized in Section 4.

## 1 Scientific Methods

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### Weight-of-evidence review

Most of what we encounter in our every day environment has no effect on our health. Other exposures, however, may affect our health in either a beneficial or a harmful way, including such ubiquitous interactions with our environment as the air we breathe, the water we drink, and our exposure to sunlight. Much time and money is spent by scientists around the world designing, conducting, and publishing research to determine what factors may affect our health, including environmental exposures (like ELF EMF), infectious agents, and our genetics. The process for arriving at a conclusion about whether there is a health risk associated with any of these factors often is not straightforward or definitive. Rather, it is a long process that requires repeated hypothesis generation and testing.

The process begins when a scientist forms a hypothesis and conducts a study to test that hypothesis. Studies are conducted by scientists at academic universities and scientific institutions around the world. Once a study is complete, the authors submit it to a scientific journal for publication, where it undergoes peer review prior to publication. The evidence to evaluate any health risk includes all of the relevant studies published in the peer-reviewed literature.

These individual research studies can be thought of as puzzle pieces. When all of the research is placed together, we have some understanding of possible health effects; no conclusions can be reached, however, by looking at only one study, just as no picture can be formed with just one puzzle piece. Each study provides a different piece of information to the puzzle because of its unique strengths and weaknesses—if the study used valid methods and had no obvious sources of bias, it may provide a wealth of information or, if the study was not well conducted, it may add little or no information to our understanding.

This process of evaluating all of the research together to determine whether something poses either a health benefit or health risk is referred to as a weight-of-evidence review. There are

three types of research that are considered in a weight-of-evidence review: epidemiology studies of people, experimental studies in animals (*in vivo* research), and experimental studies in cells and tissues (*in vitro* research). It is important to consider all three types of research together because they provide complementary information:

- Epidemiology studies collect observational data about human populations in their every day environments to determine whether there are patterns between exposures and diseases. These studies measure statistical associations to evaluate whether a disease and exposure occur together more often than expected. An important limitation of these studies is that, if an association is measured, they do not tell scientists how the exposure is truly related to the disease. That conclusion can only be reached by considering the entire body of research. Most of the studies evaluating ELF EMF examine whether people with a particular disease have had higher estimates of ELF EMF exposure in the past compared to people without that disease.
- Experimental studies in which scientists expose animals (*in vivo*) to varying levels of electric or magnetic fields (some as high as 50,000 mG) are an important source of information. These studies compare the amount of disease they observe in exposed animals to the amount of disease they observe in animals that have not been exposed. The strength of animal studies is that scientists are able to control all aspects of the animals' lives to minimize the potential confounding effects of factors other than the exposure of interest. The most valuable experimental studies for understanding disease are those in which the animals receive life-long exposures.
- Experimental studies *in vitro* involve the exposure of isolated cells and tissues to the agent of interest, in this case ELF EMF, and compare the characteristics of exposed and unexposed samples to look for differences that are indicative of a disease process. These studies are limited because what occurs to exposed cells or tissues outside of a human body may not be the same as what occurs to cells and tissues inside a body.

The weight-of-evidence approach is the standard process used worldwide by scientists, scientific organizations, and regulatory agencies to assess the possible health benefits and risks associated with exposures. A weight-of-evidence review begins with a systematic review of published, peer-reviewed epidemiology, *in vivo*, and *in vitro* research. The weight that individual studies provide to the overall conclusions is not equal—studies vary widely in terms of the sophistication and validity of their methods. Therefore, each study from each discipline must be evaluated critically and assigned a weight. A final conclusion is then reached by considering the cumulative body of research, giving more weight to studies of higher quality (Figure 1).

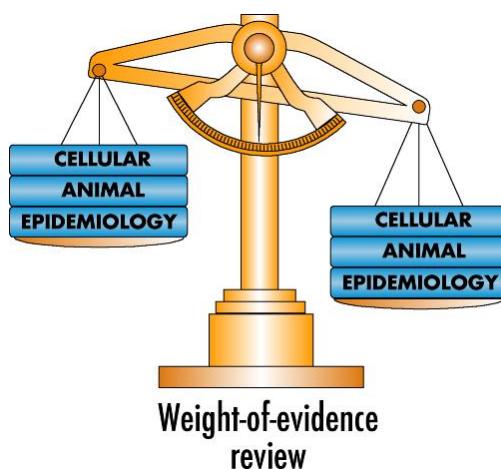


Figure 1. Weight-of-evidence reviews consider three types of research

Continuing with the puzzle example from above, the picture that is formed when the individual studies are assembled can take on many different shapes. In some cases (e.g., smoking and lung cancer), a clear picture of an adverse health effect was presented by the research within a relatively short time. In most cases, however, the picture is unclear and more questions are raised than answered. It is impossible to prove the negative in science—i.e., to say that any exposure is completely safe—therefore, research studies can only reduce the uncertainty that there is a health effect through continued research. The only way to reduce this uncertainty is to conduct high quality studies with meaningful results that are replicated across study populations (in the case of epidemiology studies) and by different laboratories (in the case of *in vivo* and *in vitro* research). Thus, in most areas of research, unless the data clearly indicate an increased

risk at defined exposure levels, scientific panels will conclude that the research is inadequate or limited and requires further study until the uncertainty has been reduced below an acceptable level. While the public may interpret this conclusion as indicating concern, it is natural for scientists to recommend future research to reduce uncertainty around a largely negative body of research or to replicate findings that appear positive.

Scientific and health organizations put together panels of scientists to conduct weight-of-evidence reviews. These panels consist of experts from around the world in the areas of interest (e.g., epidemiology, neurophysiology, toxicology, etc.) and they follow standard scientific methods for arriving at conclusions about possible health risks. The conclusions of these reviews are looked to for the current scientific consensus on a particular topic and form the basis of recommendations made by organizations and governments on exposure standards and precautionary measures.

## **Scientific reviews on ELF EMF**

Numerous national and international organizations responsible for public health have convened multidisciplinary panels of scientists to conduct weight-of-evidence reviews and arrive at conclusions about the possible risks associated with ELF EMF. These organizations include the following (in ascending, chronological order of their most recent publication):

- The **National Institute for Environmental Health Sciences (NIEHS)** in the United States assembled a 30-person Working Group to review the cumulative body of epidemiologic and experimental data on ELF EMF and provide conclusions and recommendations to the government (NIEHS, 1998, 1999).
- The **International Agency for Research on Cancer (IARC)** completed a full carcinogenic evaluation of ELF EMF in 2002 (IARC, 2002).
- The **World Health Organization (WHO)** released a review in June 2007 as part of its International EMF Program to assess the scientific evidence related to ELF EMF in the frequency range from 0 to 300 GHz (WHO, 2007a). Appendix 1 summarizes the conclusions of this review.

- The **Swedish Radiation Protection Authority (SSI)**,<sup>4</sup> using other major scientific reviews as a starting point, evaluated new studies in consecutive annual reports (SSI, 2007; SSI, 2008).
- The **Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR)** issued a report in March 2007 and March 2009 (SCENIHR, 2007; SCENIHR, 2009) updating previous conclusions (SSC, 1998; CSTEE, 2001) to the Health Directorate of the European Commission.
- The **National Radiological Protection Board (NRPB)**<sup>5</sup> of the United Kingdom issued full evaluations of the research in 1992, 2001, and 2004, with supplemental updates (NRPB, 1993; NRPB, 1994a) and topic-specific reports (NRPB, 1994b; NRPB, 2001b; HPA, 2006) published in the interim. In a letter addressing a related topic, the Director of the Health Protection Agency of Great Britain (HPA) reiterated their position on ELF EMF and appropriate precautionary measures (HMG, 2009).
- The **International Commission on Non-Ionizing Radiation Protection (ICNIRP)**, the formally recognized organization for providing guidance on standards for non-ionizing radiation exposure for the WHO, published a review of the cumulative body of epidemiologic and experimental data on ELF EMF in 2003. The ICNIRP released draft exposure guidelines for ELF EMF in July 2009 (ICNIRP, 2009). While the ICNIRP panel stated that they relied heavily on previous reviews of the literature related to long-term ELF EMF exposures, they provided relevant conclusions as part of the drafting of these guidelines. Final guidelines for ELF EMF exposure were issued in late 2010 (ICNIRP, 2010).

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<sup>4</sup> The Swedish Radiation Safety Authority (Strål säkerhets myndigheten [SSM]) has superseded the SSI, which ceased to exist on 30 June 2008. The SSM is a managing authority of Sweden's Ministry of the Environment and has “national collective responsibility within the areas of radiation protection and nuclear safety,” which includes EMF research (<http://www.stralsakerhetsmyndigheten.se>).

<sup>5</sup> The NRPB merged with the Health Protection Agency in April 2005 to form its new Radiation Protection Division.

## Dissenting opinion on ELF EMF

In August 2007, an *ad hoc* group of 14 scientists and public health and policy consultants published an on-line report titled “*The BioInitiative Report: A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF)*.” The group’s objective was to “assess scientific evidence on health impacts from electromagnetic radiation below current public exposure limits and evaluate what changes in these limits are warranted now to reduce possible public health risks in the future” (p. 4). The report was followed by several publications related to ELF EMF that summarized some of the online report’s conclusions (Hardell and Sage, 2008; Davanipour and Sobel, 2009; Johansson 2009). The individuals who comprised this group did not represent any well-established regulatory agency nor were they convened by a recognized scientific authority. The report has been criticized by scientific agencies because it did not follow the methods of a standard weight-of-evidence review and, for this reason, its conclusions and recommendations are not considered further in this report (Danish National Board of Health, 2007; ACRBR, 2008; HCN, 2008).<sup>6</sup> Appendix 3 provides a full criticism of the report.

## Epidemiology basics

This section briefly describes the main types of epidemiology studies and the major issues that are relevant to evaluating their results. The two, main types of epidemiology studies are cohort studies and case-control studies (Figure 2).

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<sup>6</sup> <http://www.gezondheidsraad.nl/en/publications/bioinitiative-report-0>

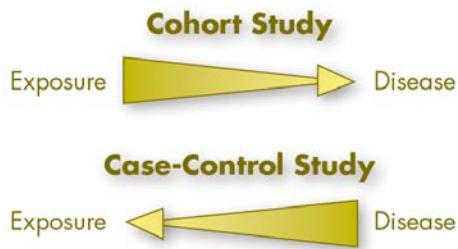


Figure 2. Basic design of cohort and case-control studies

A case-control study compares the characteristics of people that have been diagnosed with a disease (i.e., cases) to a similar group of people who do not have the disease (i.e., controls). The prevalence and extent of past exposure to a particular agent is estimated in both groups and compared to assess whether the cases have a higher exposure level than the controls, or vice versa.

In a case-control study, this comparison (or statistical association) is estimated quantitatively with an odds ratio (OR). An OR is the ratio of the odds of exposure among persons with a disease to the odds of exposure among persons without a disease. The general interpretation of an OR equal to 1.0 is that the odds of exposure are the same in the case and control groups (i.e., there is no statistical association between the exposure and disease). If the OR is greater than 1.0, the inference is that the odds of exposure are greater in the case group or, in other words, the exposure may increase the risk of the disease (Figure 3).

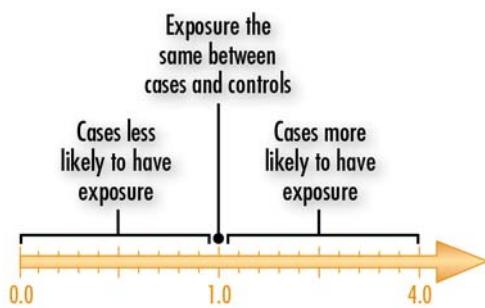


Figure 3. Interpretation of an odds ratio in a case-control study

Each OR is reported with a confidence interval (CI), which is a range of OR values that have a specified probability of occurring if the study is assumed to be repeated a large number of times. A 95% CI, for example, provides the range of values that are likely to occur in 95% of repeated experiments. In short, a CI indicates how certain (or confident) the researcher is about the OR calculated from his or her data; if the CI includes 1.0, the researcher cannot statistically exclude the possibility that the OR is 1.0, meaning the odds of exposure are the same in the case and control groups.

A cohort study is conducted in the reverse manner—in the most traditional sense, researchers study a population *without disease* and follow them over time to see if persons with a certain exposure develop disease at a higher rate than unexposed persons. The comparisons conducted in cohort studies are similar to the comparisons conducted in case-control studies, although the risk estimate is referred to as a relative risk (RR) rather than an OR. The RR is equal to rate of disease in the exposed group divided by the rate of disease in the unexposed group, with values greater than 1.0 suggesting that the exposed group has a higher rate of disease.

The resulting RR or OR is simply a comparative measure of how often a disease and exposure occur together in exposed and unexposed study populations—it does not mean that there is a known or causal relationship. Before any conclusions can be drawn, all studies considering a particular exposure and disease must be identified, and each study must be evaluated to

determine the possible role that factors such as chance, bias, and confounding may have played in the study's results.

- *Chance* refers to a random event, i.e., a coincidence. An association can be observed between an exposure and disease that simply is the result of a chance occurrence. Statistics, such as the CI, are calculated to determine whether chance is a likely explanation for the findings.
- *Bias* refers to any error in the design, conduct, or analysis of a study that would cause a distorted estimate of an exposure's effect on the risk of disease. There are many different types of bias; for example, selection bias may occur if the characteristics of persons that participate in a study differ in a meaningful way from the characteristics of those subjects that do not participate (e.g., cases living near power lines might be more likely to participate than controls because the cases are concerned about this possible exposure).
- *Confounding* is a situation in which an association is distorted because the exposure being studied is associated with other risk factors for the disease. For example, a link between coffee drinking in mothers and low birth weight babies may be observed in a study, but some women who drink coffee also smoke cigarettes. When the smoking habits of mothers are taken into account, coffee drinking may not be associated with low birth weight babies because the confounding effect of smoking has been removed.

As part of the weight-of-evidence review process, each study's design and methods are evaluated critically to determine if and how chance, bias, and confounding may have affected the results and, subsequently, the weight that should be placed on the study's findings.

## IARC classifications

This section briefly describes the method that the IARC uses following a weight-of-evidence review to classify exposures based on the evidence in support of carcinogenicity. The WHO adopted this method in their 2007 review on ELF EMF, and other scientific agencies refer to this classification system, as well.

First, each research type (epidemiology, *in vivo*, and *in vitro*) is evaluated to determine the strength of evidence in support of carcinogenicity (as defined in Figure 4). Epidemiology studies are characterized as having *sufficient evidence* for carcinogenicity if an association is found and chance, bias, and confounding can be ruled out with “reasonable confidence.” *Limited evidence* is used to describe a body of research where the findings are inconsistent or where an association is observed but there are outstanding questions about study design or other methodological issues that preclude making strong conclusions. *Inadequate evidence* describes a body of research where it is unclear whether the data is supportive or unsupportive of causation because there is a lack of data or there are major quantitative or qualitative issues. The same overall categories apply for *in vivo* research. *In vitro* research is not described in Figure 4 because it provides ancillary information and, therefore, is used to a lesser degree in evaluating carcinogenicity and is classified simply as strong, moderate, or weak.

Agents are then classified into five overall categories using the combined categories from epidemiology, *in vivo*, and *in vitro* research (listed from highest to lowest risk): (1) known carcinogen, (2) probable carcinogen, (3) possible carcinogen, (4) non-classifiable, and (5) probably not a carcinogen.

As summarized in Figure 4, the category possible carcinogen typically denotes exposures for which there is limited evidence of carcinogenicity in epidemiology studies, and *in vivo* studies provide limited or inadequate evidence of carcinogenicity.

The IARC has reviewed over 900 substances and exposure circumstances to evaluate their potential carcinogenicity. Figure 5 provides examples of some of the more common exposures that have been classified in each category. As Figure 5 shows, over 80% of exposures fall in the categories possible carcinogen (27%) or non-classifiable (55%). This occurs because, as described above, it is nearly impossible to prove that something is completely safe and few exposures show a clear-cut or probable risk, so most agents will end up in either of these two categories. Throughout the history of the IARC, only one agent has been classified as probably not a carcinogen, which illustrates the conservatism of the evaluations and the difficulty in proving the absence of an effect beyond all doubt.

Over half of the agents are non-classifiable in terms of carcinogenicity, i.e., it is unclear whether they can cause cancer—hair coloring products, jet fuel, and tea are included in this category. Possible carcinogens include occupation as a firefighter, coffee, and pickled vegetables, in addition to magnetic fields. Exposures identified as probable carcinogens include high temperature frying and occupation as a hairdresser. Finally, known carcinogens include benzene, asbestos, solar radiation, use of tanning beds, and tobacco smoking. As Figure 5 shows, there is much uncertainty about whether certain agents will lead to cancer, and possible and probable carcinogens include substances to which we are commonly exposed or are common exposure circumstances.

	Epidemiology Studies				Animal Studies			
	Sufficient evidence	Limited evidence	Inadequate evidence	Evidence suggesting lack of carcinogenicity	Sufficient evidence	Limited evidence	Inadequate evidence	Evidence suggesting lack of carcinogenicity
Known Carcinogen	✓							
Probable Carcinogen		✓			✓			
Possible Carcinogen		✓				✓	✓	
Not Classifiable			✓			✓	✓	
Probably not a Carcinogen				✓				✓

**Sufficient evidence in epidemiology studies**—A positive association is observed between the exposure and cancer in studies, in which chance, bias and confounding were ruled out with “reasonable confidence.”

**Limited evidence in epidemiology studies**—A positive association has been observed between the exposure and cancer for which a causal interpretation is considered to be credible, but chance, bias or confounding could not be ruled out with “reasonable confidence.”

**Inadequate evidence in epidemiology studies**—The available studies are of insufficient quality, consistency or statistical power to permit a conclusion regarding the presence or absence of a causal association between exposure and cancer, or no data on cancer in humans are available.

**Evidence suggesting a lack of carcinogenicity in epidemiology studies**—There are several adequate studies covering the full range of levels of exposure that humans are known to encounter, which are mutually consistent in not showing a positive association between exposure to the agent and any studied cancer at any observed level of exposure. The results from these studies alone or combined should have narrow confidence intervals with an upper limit close to the null value (e.g. a relative risk of 1.0). Bias and confounding should be ruled out with reasonable confidence, and the studies should have an adequate length of follow-up.

**Sufficient evidence in animal studies**—An increased incidence of malignant neoplasms is observed in (a) two or more species of animals or (b) two or more independent studies in one species carried out at different times or indifferent laboratories or under different protocols. An increased incidence of tumors in both sexes of a single species in a well-conducted study, ideally conducted under Good Laboratory Practices, can also provide sufficient evidence.

**Limited evidence in animal studies**—The data suggest a carcinogenic effect but are limited for making a definitive evaluation, e.g. (a) the evidence of carcinogenicity is restricted to a single experiment; (b) there are unresolved questions regarding the adequacy of the design, conduct or interpretation of the studies; etc.

**Inadequate evidence in animal studies**—The studies cannot be interpreted as showing either the presence or absence of a carcinogenic effect because of major qualitative or quantitative limitations, or no data on cancer in experimental animals are available.

**Evidence suggesting a lack of carcinogenicity in animal studies**—Adequate studies involving at least two species are available which show that, within the limits of the tests used, the agent is not carcinogenic.

Figure 4. Basic IARC method for classifying exposures based on potential carcinogenicity

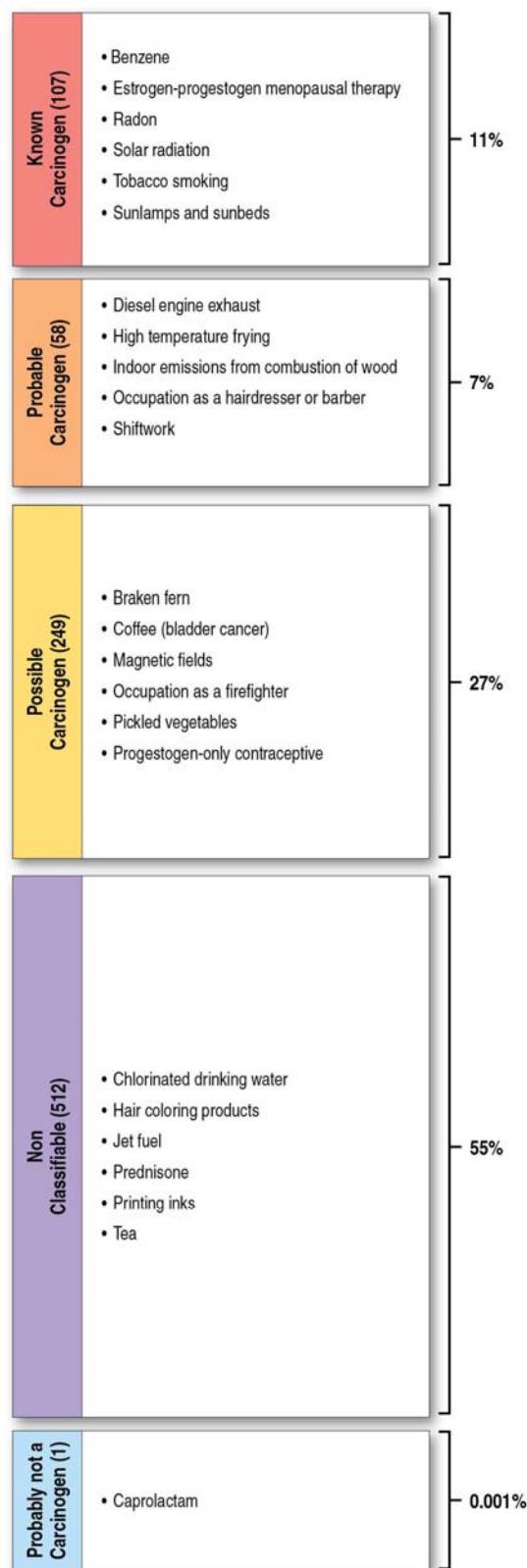


Figure 5. Percentage of substances classified in each IARC category with examples

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## **2 Human Health Research**

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The following sections provide an overview of peer-reviewed research published between January 1, 2006 and October 1, 2010. A literature review was conducted to identify new epidemiologic, *in vivo*, and *in vitro* research published on 50 or 60-Hz ELF EMF. A large number of search strings referencing the exposure and diseases of interest, as well as authors who regularly publish in this area, were included as search terms in the PubMed database, a service of the U.S. National Library of Medicine that includes over 17 million citations from MEDLINE and other life science journals for biomedical articles dating to the 1950s.<sup>7</sup> A scientist with experience in this area reviewed the search results to identify relevant studies.

This report focuses on the diseases that have received the most attention—cancer, reproductive effects, developmental effects, and neurodegenerative diseases. Other health effects have been studied (i.e., rare cancer types, suicide, depression, electrical hypersensitivity, and cardiovascular effects), but for brevity and because research on these topics evolves slowly, these topics are not summarized here. The WHO review provides a good resource for the status of research on these additional health effects.

This update focuses on identifying and summarizing new epidemiologic and major *in vivo* research, since these study types are the most informative for risk assessment in this field; for the status of *in vitro* research, we include our discussion from the July 2007 report.

### **Cancer**

#### **Childhood leukemia**

##### **What was previously known about childhood leukemia and what did the WHO review conclude?**

Scientific panels have concluded consistently that magnetic fields are a possible carcinogen largely because of findings from studies of childhood leukemia. Since 1979, approximately 35

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<sup>7</sup> PubMed includes links to full text articles and other related resources (<http://www.ncbi.nlm.nih.gov/PubMed/>).

studies conducted in the United States, Canada, Europe, New Zealand, and Asia have evaluated the relationship between childhood leukemia and magnetic fields using various methods to estimate exposure. These methods have included long-term (48-hour) personal monitoring; spot or long-term (24- or 48-hour) measurements in structures and outdoors; calculations using loading, line configuration, and distance of nearby power installations to estimate historical, residential exposure; and wire code categories.<sup>8</sup> As a group of independent studies, they did not show a clear or consistent association between magnetic fields and childhood leukemia. The largest and most methodologically sound case-control studies to estimate personal magnetic field exposure directly did not report a consistent relationship (Linet et al., 1997; McBride et al., 1999; UKCCS, 2000). When two independent pooled analyses combined the data from these case-control studies, however, a statistically significant association was observed between rare average magnetic field exposure above 3-4 mG and childhood leukemia (Ahlbom et al., 2000; Greenland et al., 2000). Both pooled analyses indicated that children with leukemia were about two times more likely to have had estimated magnetic field exposures above 3-4 mG. Average exposures at this level are uncommon; according to the WHO, results from several extensive surveys showed that approximately 0.5–7.0% of children had time-averaged exposures in excess of 3 mG and 0.4–3.3% had time-averaged exposures in excess of 4 mG (WHO, 2007a). While these analyses provide a valuable quantitative summary of the data, pooled analyses are limited by the disparate methods used to collect the underlying data. Questions have been raised as to whether the original studies, particularly those that are large and estimated exposure directly, provide a more valid estimate of the association than the pooled analyses (Elwood, 2006).

Despite the association observed in these pooled analyses, health agencies have not concluded that magnetic fields are a known or probable cause of childhood leukemia. The studies are of insufficient strength to rule out with “reasonable confidence” the role that chance, bias, and confounding may have had on the observed statistical association. In other words, researchers do not have enough confidence in the way these studies were conducted to conclude that the measured statistical association represents a true relationship between magnetic fields and childhood leukemia. Furthermore, experimental data do not provide evidence for a risk in the

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<sup>8</sup> Wire code categories are categories used to classify the potential magnetic field exposures at residences based on the characteristics of nearby power installations.

more highly-controlled *in vivo* studies, and *in vitro* studies do not provide evidence of a plausible biological mechanism whereby magnetic fields lead to carcinogenesis.

Since chance, bias, and confounding could not be ruled out as an explanation for the association, the IARC concluded in 2002 that the data on childhood leukemia provided limited evidence of carcinogenicity (IARC, 2002). In 2007, the WHO reviewed studies on childhood leukemia and magnetic field exposure published since the 2002 IARC review (WHO, 2007a). They concluded that the new epidemiologic studies were consistent with the classification of limited epidemiologic evidence in support of carcinogenicity and, together with the largely negative *in vivo* and *in vitro* research, consistent with the classification of magnetic fields as a possible carcinogen (Figure 4).<sup>9</sup>

Since it is unclear whether the association is real, the WHO review evaluated other factors that might be partially, or fully, responsible for the association, including chance, control selection bias, confounding from hypothesized or unknown risk factors, and misclassification of magnetic field exposure (Figure 6). The following is a summary of their evaluation:

- ✓ The WHO review concluded that **chance** is an unlikely explanation since the pooled analyses had a large sample size and decreased variability.
- ✓ **Control selection bias** occurs when the controls that decide to participate in the study do not represent the true exposure experience of the non-diseased population. In the case of magnetic fields, the WHO speculates that controls with a higher socioeconomic status (SES) may participate in studies more often than controls with a lower SES. Since persons with a higher SES may have lower magnetic field exposures or tend to live farther from transmission lines, the control group's magnetic field exposure may be artificially low. Thus, when the exposure experience of the control group is compared to the case group, there is a difference between the case and control group that does not exist in the source population. The WHO concluded that **control selection bias** is

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<sup>9</sup> The WHO concluded the following: "Consistent epidemiological evidence suggests that chronic low intensity ELF magnetic field exposure is associated with an increased risk of childhood leukaemia. However, the evidence for a causal relationship is limited, therefore exposure limits based upon epidemiological evidence are not recommended, but some precautionary measures are warranted" (p. 355-6, WHO, 2007a).

probably occurring in these studies and would result in an overestimate of the true association, but would not explain the entire observed statistical association

- ✓ The WHO panel concluded that **confounding** is less likely to be causing the observed association than other factors, although the possibility that some yet-to-be identified confounder is responsible for the association cannot be excluded completely. Suggested risk factors that may be confounding the relationship include SES, residential mobility, contact currents, and traffic density.<sup>10</sup>
- ✓ The WHO stated that the possible effects of **exposure misclassification** are the most difficult to predict. EMF presents unique challenges in exposure assessment because it is ubiquitous, imperceptible, and has many sources (Kheifets and Oksuzyan, 2008). No target exposure or exposure window has been identified, and the numerous methods of estimating exposure likely result in a different degree of error within and between studies. Most reviews have concluded that exposure misclassification would likely result in an underestimate of the true association, meaning the association we observe is lower than the true value; however, the extent to which this might occur varies widely and is difficult to assess (Greenland et al., 2000). The WHO concluded that exposure misclassification likely is present in these studies, but is unlikely to provide an entire explanation for the association.

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<sup>10</sup> For example, if dwellings near power lines encounter higher traffic density and pollution from traffic density causes childhood leukemia, traffic density may cause an association between magnetic field exposure and childhood leukemia, where a relationship does not truly exist.

Observation	Possible Explanation	Likelihood
Epidemiologic studies show an association between exposure to magnetic fields above 3–4 mG and childhood leukemia	Statistical Artifacts?	Chance Selection bias Exposure misclassification Confounding Mixture of above
	Causal Link?	Initiation Promotion Epigenetic
		Unlikely due to robust findings Definite but unclear whether responsible for entire association Unlikely to produce positive association Unlikely due to requirements Possible
		Unlikely due to negative experimental data Possible, no supportive data Theoretically possible, no supportive data

Source: Adapted from Schüz and Ahlbom (2008)

Figure 6. Possible explanations for the observed association between magnetic fields and childhood leukemia

The WHO review stated that reconciling the epidemiologic data on childhood leukemia and the negative (i.e., no hazard or risk observed) experimental findings through innovative research is currently the highest priority in the field of ELF EMF research. Given that few children are expected to have average magnetic field exposures greater than 3-4 mG, however, the WHO stated that the public health impact of magnetic fields on childhood leukemia would be low if the association was determined to be causal.

### What relevant studies have been published since the WHO review?

A number of studies investigating childhood leukemia and magnetic fields have been published since the WHO review (Table 1). Recent studies continue to support a weak association between elevated magnetic field levels and childhood leukemia, but they lack the methodological improvements required to advance this field; the evidence remains limited and the observed statistical association is still unexplained. Some scientists have opined that epidemiology has reached its limits in this area and any future research must demonstrate a significant methodological advancement (e.g., an improved exposure metric or a large sample size in high exposure categories) to be justified (Savitz, 2010; Schmiedel and Blettner, 2010).

Most notably, Kheifets et al. (2010a) conducted a pooled analysis of studies published between 2000 and 2010 that was intended to mirror the earlier pooled analyses of studies published between 1974 and 1999 (Ahlbom et al., 2000; Greenland et al., 2000). Kheifets et al. identified six studies for the main analysis that met their inclusion criteria (i.e., population-based studies of childhood leukemia that measured or calculated magnetic fields inside a home); three of the studies in this analysis were considered in the WHO review, while two are described here (Kroll et al., 2010; Malagoli et al., 2010).<sup>11</sup> An additional Brazilian study remains unpublished, but the results were provided via personal communication to Kheifets et al. (Wunsch Filho, personal communication, 2009).<sup>12</sup> A large number of cases were identified by Kheifets et al. (10,865), but a relatively small number of cases (23) were classified in the highest exposure category ( $>3$  mG). A positive association was reported ( $OR=1.44$ ), but it was weaker than the previous pooled estimates and not statistically significant (95% CI=0.88–2.36); a dose-response relationship was apparent and the association was stronger when the Brazilian study was excluded.

The largest number of cases in Kheifets et al. (2010a) was from a large, case-control study conducted in the United Kingdom by Kroll et al. (2010). Kroll et al. expands upon an earlier study (Draper et al., 2005) by replacing residential distance to nearby transmission lines as the exposure metric with calculated magnetic fields from nearby transmission lines; both studies included all children diagnosed with cancer in the United Kingdom from 1962 through 1995. Draper et al. (2005) reported that children with leukemia were more likely to have lived at birth within 600 meters (m) of a high-voltage transmission line, although the authors questioned the significance of this finding since magnetic fields from power lines do not extend to distances of 600 m.<sup>13</sup> Kroll et al. calculated average yearly residential magnetic-field levels for children

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<sup>11</sup> A seventh study was included in Kheifets et al. (2010a), but only in the pooled analysis of childhood leukemia and residential distance to power lines (Lowenthal et al., 2007). This study is not discussed further in this section because published findings only report on a combined category of lymphoproliferative and myeloproliferative disorders for both adults and children combined.

<sup>12</sup> The study evaluated acute lymphoblastic leukemia among children less than 8 years of age and measured exposure using 24-hour measurements in the children's bedrooms.

<sup>13</sup> The WHO concluded the following with respect to the Draper et al. (2005) findings: “[the] observation of the excess risk so far from the power lines, both noted by the authors and others, is surprising. Furthermore, distance is known to be a very poor predictor of magnetic field exposure, and therefore, results of this material based on calculated magnetic fields, when completed, should be much more informative” (p. 270, WHO 2007a).

living within 400 m of power lines at birth; modeling estimated that magnetic field levels above 1 mG could be predicted reliably only at residences within 400 m of a transmission line. Only 1% of children had a residence at birth within 400 m of a transmission line and only 0.07% had calculated exposures greater than 1 mG. Furthermore, nearly 25% of the residences within 400 m of a transmission line lacked data to calculate residential magnetic-field levels. An OR of 2.0 was calculated for the two cases of childhood leukemia and one control with calculated magnetic fields greater than 4 mG (95% CI=0.18 to 22.04); no dose-response relationship was apparent. As a result of small numbers and incomplete information, no strong conclusions can be drawn from this study. The authors stated that the study “slightly strengthens” the evidence for an association between magnetic fields and childhood leukemia.

Malagoli et al. (2010) was also included in the pooled analysis. This Italian study identified all childhood hematological malignancies diagnosed between 1967 and 2007 in two Italian municipalities (64 cases) and recruited four controls per case matched on sex, age, and municipality of residence.<sup>14</sup> Exposure was defined as having lived for at least 6 months prior to diagnosis at a residence with calculated power-line magnetic field levels above 1 mG or above 4 mG; magnetic-field levels were calculated using 2001 average line loading, rather than loading during the year of birth or diagnosis. Few children lived in a residence with power-line magnetic field levels above 1 mG (2 cases and 5 controls) or 4 mG (1 case and 2 controls); thus, estimated associations were unstable. The RR for leukemia and residence in an area with exposure  $\geq$ 1 mG was 3.2 (6.7 adjusting for SES), but the estimate was statistically unstable (95% CI=0.4-23.4), and there was no indication of a dose-response relationship. Similar to Kroll et al. (2010), this study’s strength is the lack of participation required, but it is limited by small numbers, the related imprecision, and the lack of an exposure-response relationship.

Three studies published since the WHO review confirmed an association with residential distance to power lines and childhood leukemia in countries with populations living in closer proximity to power lines (Feizi and Arabi, 2007 [ $<$  500 m vs.  $>$ 500 m]; Abdul Rahman et al., 2008 [ $<$  200 m vs.  $>$ 200 m]; Sohrabi et al., 2010 [ $<$ 400 m vs.  $>$ 400 m]). The consistency of the association between childhood leukemia and residential distance to power lines is noteworthy,

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<sup>14</sup> Hematological cancers include all types of leukemias, lymphomas, and Hodgkin’s disease.

but these studies do not provide strong evidence of a relationship between magnetic fields and childhood leukemia because of their limited quality, e.g., lack of control for SES. While these three studies were excluded from the pooled analysis because they were hospital-based, Kheifets et al. (2010a) pooled data on distance and childhood leukemia from other studies and confirmed an elevated OR at distances less than 200 m. The association remains unexplained, however, and a recent study confirms that distance is a poor proxy for measurements of residential magnetic fields; Maslanyj et al. (2009) reported that only 13% of homes in a 100 m corridor of 220-440-kV power lines had a measured magnetic field level above 2 mG.

Other recent studies were not included in the pooled analysis because they reported on leukemia subgroups and magnetic fields. These studies reported that children with leukemia and estimates of average magnetic-field exposures greater than 3-4 mG had poorer survival (Foliart et al., 2006, 2007; Svendsen et al., 2007); children with Down syndrome and childhood leukemia were more likely to have spot measurements at the door of their home greater than 6 mG compared to children with Down syndrome only (Mejia-Arangure et al., 2007); and one genetic polymorphism related to DNA repair (but with no known relationship to leukemia) was reported to be more common among children with leukemia living close to an electrical installation compared to children with leukemia living at a distance (Yang et al., 2008). The results of these recent studies were limited by small numbers, incomplete adjustment for potential risk factors, and the lack of a biological explanation to explain the observed associations, among other methodological issues. Additional epidemiologic and biological research is required in these new fields of inquiry.

Another new field of inquiry is the relevance of pre- or post-conception EMF exposure of a parent to cancer in their offspring. Hug et al (2010) studied the pre-conception occupational exposures of parents of children with leukemia and compared them to the exposures of parents of healthy children. No association was found between childhood leukemia and magnetic-field exposure pre-conception in either parent. Another recent study reported an association between childhood leukemia and a paternal history of electrical work, but is limited because exposure is based solely on occupational title (Pearce et al., 2007).

Scientists have also pursued the influence of bias and confounding in recent years. Recent studies confirmed that control selection bias appears to be operating in case-control studies of childhood leukemia and magnetic fields, although the exact degree of its influence is still unknown (Mezei and Kheifets, 2006; Mezei et al., 2008a, 2008b). A study has also found that contact currents from residential grounding systems show characteristics of a confounding variable (Kavet and Hooper, 2009). Finally, a recent study confirmed that the time of day when magnetic-field measurement are made is not contributing to exposure misclassification; no difference in the magnitude or pattern of results was found for nighttime vs. 24-hour or 48-hour measurements, refuting the hypothesis that nighttime exposures are more strongly associated with childhood leukemia because magnetic fields might affect carcinogenesis through a melatonin-driven pathway (Schüz et al., 2007).

In summary, the studies conducted since the WHO review support an association with magnetic fields and childhood leukemia. In particular, scientific data published since the WHO review:

- confirms the rarity of living in close proximity to a power line or having estimated or measured exposures greater than 1 mG;
- confirms a positive association between average magnetic field levels greater than 3 mG and childhood leukemia, but the association cannot be distinguished from chance due to small numbers;
- confirms an association with residential proximity to power lines and childhood leukemia, but reports that distance is not a reliable predictor of in-home magnetic field levels; and,
- suggests that control selection bias may play some role in the observed association.

These findings do not alter previous conclusions that the epidemiologic evidence on magnetic fields and childhood leukemia is limited. Chance, confounding, and several sources of bias cannot be ruled out. Conclusions from reviews (Kheifets and Oksuzyan, 2008; Schüz and Ahlbom, 2008) and scientific organizations (SSI, 2007; SSI, 2008; HCN, 2009; SCENIHR, 2009) published since the WHO review support this conclusion.

**Table 1.** Relevant studies of childhood leukemia published after the WHO review

<b>Author</b>	<b>Year</b>	<b>Study Title</b>
Abdul Rahman et al.	2008	A case-control study on the association between environmental factors and the occurrence of acute leukemia among children in Klang Valley, Malaysia.
Fezei and Arabi	2007	Acute childhood leukemias and exposure to magnetic fields generated by high voltage overhead power lines – a risk factor in Iran
Foliart et al.	2006	Magnetic field exposure and long-term survival among children with leukaemia
Foliart et al.	2007	Magnetic field exposure and prognostic factors in childhood leukemia
Hug et al.	2010	Parental occupational exposure to extremely low frequency magnetic fields and childhood cancer: a German case-control study
Kavet and Hooper	2009	Residential magnetic fields and measures of neutral-to-earth voltage: variability within and between residences
Kheifets et al.	2010a	Pooled analysis of recent studies on magnetic fields and childhood leukaemia
Kroll et al.	2010	Childhood cancer and magnetic fields from high-voltage power lines in England and Wales: a case-control study
Malagoli et al.	2010	Risk of hematological malignancies associated with magnetic fields exposure from power lines: a case control study in two municipalities in northern Italy
Maslanyj et al.	2009	Power frequency magnetic fields and risk of childhood leukaemia: Misclassification of exposure from the use of the 'distance from power line' exposure surrogate
Mejia-Arangure et al.	2007	Magnetic fields and acute leukemia in children with Down syndrome
Mezei and Kheifets	2006	Selection bias and its implications for case-control studies: A case study of magnetic field exposure and childhood leukaemia
Mezei et al.	2008a	Assessment of selection bias in the Canadian case-control study of residential magnetic field exposure and childhood leukemia
Pearce et al.	2007	Paternal occupational exposure to electro-magnetic fields as a risk factor for cancer in children and young adults: A case-control study from the North of England
Schüz et al.	2007	Nighttime exposure to electromagnetic fields and childhood leukemia: An extended pooled analysis
Sohrabi et al.	2010	Living near overhead high voltage transmission power lines as a risk factor for childhood acute lymphoblastic leukemia: a case-control study
Svendson et al.	2007	Exposure to magnetic fields and survival after diagnosis of childhood leukemia: An extended pooled analysis
Yang et al.	2008	Case-only of interactions between DNA repair genes (hMLH1, APEX1, MGMT, XRCC1, and XPD) and low frequency electromagnetic fields in childhood acute leukemia

## Childhood brain cancer

### What was previously known about childhood brain cancer and what did the WHO review conclude?

The research related to magnetic fields and childhood brain cancer has been less consistent than that observed for childhood leukemia. The WHO review recommended the following:

*As with childhood leukaemia, a pooled analysis of childhood brain cancer studies should be very informative and is therefore recommended. A pooled analysis of this kind can inexpensively provide a greater and improved insight into the existing data, including the possibility of selection bias and, if the studies are sufficiently homogeneous, can offer the best estimate of risk (p. 18, WHO 2007a).*

### What relevant studies have been published since the WHO review?

The relevant studies of childhood brain cancer and magnetic field exposure are listed in Table 2 below. In response to the WHO recommendation above, a meta-analysis (Mezei et al., 2008b) and a pooled analysis (Kheifets et al., 2010b) of studies on childhood brain tumors and residential magnetic field exposure were conducted. In the meta-analysis, thirteen epidemiologic studies were identified that used various proxies of magnetic field exposure (distance, wire codes, calculated magnetic fields, and measured magnetic fields). The combined effect estimate was close to 1.0 and not statistically significant, indicating no association between magnetic field exposure and childhood brain tumors. A sub-group of five studies, however, with information on childhood brain tumors and calculated or measured magnetic fields greater than 3-4 mG reported a combined OR that was elevated but not statistically significant (OR=1.68, 95% CI=0.83-3.43). The authors suggested two explanations for this elevated OR. First, they suggested that an increased risk of childhood brain tumors could not be excluded at high exposure levels (i.e., >3-4 mG). Second, they stated that the similarity of this result to the findings of the pooled analyses of childhood leukemia suggests that control selection bias is operating in both analyses. Similar to the meta-analysis, some categories of high exposure in the pooled analysis of studies with measured or calculated magnetic-field levels had an OR  $\geq 1.0$ , but none of the findings were statistically significant and enhanced calculations showed inconsistency in the results of subgroup analyses and no dose-response pattern (Kheifets et al., 2010b). The main analysis reported no association between childhood brain cancer and magnetic-field exposure  $>4$  mG, compared to

magnetic-field exposure <1 mG (OR=1.14, 95% CI=0.61-2.13). Both the authors of the meta-analysis and the pooled analysis concluded that their results provide little evidence for an association between magnetic fields and childhood brain tumors.

The pooled analysis included two case-control studies published after the WHO 2007 review (Kroll et al., 2010; Saito et al., 2010). In their study of 55 cases of childhood brain cancer, Saito et al. (2010) reported that children with brain cancer were more likely to have average magnetic-field exposure levels greater than 4 mG, compared to children without brain cancer.<sup>15</sup> The association was based on three cases and one control; interpretations of the data were, therefore, limited by small numbers in the upper exposure category. The strength of this study is the exposure assessment; measurements were taken continuously over a weeklong period in the child's bedroom approximately 1 year after diagnosis. An important limitation, however, is the very poor participation rates among study subjects; poor participation rates introduce the possibility of selection bias, among other biases. As described above, Kroll et al. (2010) included 6,584 cases of brain cancer diagnosed over a 33-year period in the United Kingdom. No associations were reported in any analysis of brain cancer, including calculated magnetic fields  $\geq 1\text{-}2$  mG, 2-4 mG, and 4mG.

Studies of parental occupational magnetic field exposure and childhood brain tumors have produced inconsistent results. In a recent pooled analysis of two Canadian case-control studies, Li et al. (2009) calculated individual maternal occupational magnetic field exposure pre- and post-conception and analyzed these estimates in relation to brain cancer in offspring. Associations were reported between childhood brain cancer and average magnetic-field exposures greater than approximately 3 mG for exposure in the 2 years prior to conception and during conception; no associations were found using the cumulative and peak exposure metrics. More research is required in this area.

Recent studies provide some suggestion of an association between magnetic field exposures prior to diagnosis or *in utero* and the development of childhood brain cancer. The data receive little weight in an overall assessment, however, due to methodological shortcomings. The recent data do not alter the classification of the epidemiologic data in this field as inadequate.

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<sup>15</sup> The unpublished results of this study were included in Mezei et al. (2008b).

**Table 2. Relevant studies of childhood brain cancer published after the WHO review**

<b>Authors</b>	<b>Year</b>	<b>Study</b>
Kheifets et al.	2010b	A pooled analysis of extremely low-frequency magnetic fields and childhood brain tumors
Kroll et al.	2010	Pooled analysis of recent studies on magnetic fields and childhood leukaemia
Li et al.	2009	Maternal occupational exposure to extremely low frequency magnetic fields and the risk of brain cancer in the offspring
Mezei et al.	2008b	Residential magnetic field exposure and childhood brain cancer: a meta-analysis
Saito et al.	2010	Power frequency magnetic fields and childhood brain tumors: A case-control study in Japan

## Breast cancer

### **What was previously known about breast cancer and what did the WHO review conclude?**

The WHO reviewed studies of breast cancer and residential magnetic field exposure, electric blanket usage, and occupational magnetic field exposure. These studies did not report consistent associations between magnetic field exposure and breast cancer, and the WHO concluded that, since the recent body of research was higher in quality compared with previous studies, it provided strong support to previous consensus statements that magnetic field exposure does not influence the risk of breast cancer.<sup>16</sup> The WHO recommended no further research with respect to breast cancer and magnetic field exposure.

### **What relevant studies have been published since the WHO review?**

Two case-control studies (McElroy et al., 2007; Ray et al., 2007) and one cohort study (Johansen et al., 2007) have been published, all of which evaluated occupational magnetic field exposure.<sup>17</sup> In addition, a meta-analysis of 15 studies of breast cancer and occupational

<sup>16</sup> The WHO concluded, “Subsequent to the IARC monograph a number of reports have been published concerning the risk of female breast cancer in adults associated with ELF magnetic field exposure. These studies are larger than the previous ones and less susceptible to bias, and overall are negative. With these studies, the evidence for an association between ELF exposure and the risk of breast cancer is weakened considerably and does not support an association of this kind” (p. 307, WHO 2007a).

<sup>17</sup> In addition to the studies described in the text, another study was identified. Peplonska et al. (2007) is a case-control study of female breast cancer reporting associations for a wide range of occupations and industries. It is not considered in depth in this report because no qualitative or quantitative estimates of magnetic field exposure were made, beyond occupation and industry titles.

magnetic field exposure was published (Chen et al., 2010), which included one of the case-control studies (McElroy et al 2007).

Ray et al. (2007) was a nested case-control study in a cohort of approximately 250,000 textile workers in China followed for breast cancer incidence, and McElroy et al. (2007) evaluated occupational exposures to high, low, medium, or background EMF levels in a large number of breast cancer cases and controls. Neither study observed a significant association between breast cancer and higher estimated magnetic field exposure. A large cohort study of utility workers in Denmark also reported that women exposed to higher occupational magnetic field levels did not have higher rates of breast cancer (Johansen et al., 2007).

Chen et al. (2010) published a meta-analysis of all published case-control studies of female breast cancer and magnetic field exposure meeting defined inclusion criteria. Fifteen studies published between 2000 and 2009 were identified examining residential and occupational exposure and electric blanket usage. The authors crudely re-categorized data from the original studies to reflect a common comparison of <2 mG and >2mG and reported an overall OR of 0.988 (95% CI = 0.898–1.088). The advantage of this meta-analysis is its very large size. Its main limitation is that data from a wide range of exposure definitions and cut-points were combined.

These studies, particularly the large cohort of utility workers, add to growing support against a causal role for magnetic fields in breast cancer. This is consistent with the conclusion by the SCENIHR, which stated that an association is “unlikely” (p. 7, SCENIHR 2007).

**Table 3. Relevant studies of breast cancer published after the WHO review**

Authors	Year	Study
Chen et al.	2010	Extremely low-frequency electromagnetic fields exposure and female breast cancer risk: a meta-analysis based on 24,338 cases and 60,628 controls
Johansen et al.	2007	Risk for leukaemia and brain and breast cancer among Danish utility workers: A second follow-up
McElroy et al.	2007	Occupational exposure to electromagnetic field and breast cancer risk in a large, population-based, case-control study in the United States
Ray et al.	2007	Occupational exposures and breast cancer among women textile workers in Shanghai

## Other adult cancers

### What was previously known about other adult cancers and what did the WHO review conclude?

In general, scientific panels have concluded that there is not a strong or consistent relationship between other adult cancers (leukemia, lymphoma, or brain cancers) and exposure to magnetic fields; however, the possibility cannot be entirely ruled out because the findings have been inconsistent (IARC, 2002; WHO, 2007a). Stronger findings have not been observed in studies with better exposure assessment methods, which have led scientific panels to conclude that the evidence for an association is weak. The IARC classified the epidemiologic data with regard to adult leukemia, lymphoma, and brain cancer as “inadequate” in 2002, and the WHO confirmed this classification in 2007, with much of the remaining uncertainty attributed to limitations in exposure assessment methods.

Much of the research on EMF and adult cancers is related to occupational exposures, given the higher range of exposures encountered in the occupational environment. The main limitation of these studies, however, has been the methods used to assess exposure, with early studies relying simply on a person’s occupational title (often taken from a death certificate) and later studies linking a person’s full or partial occupational history to representative average exposures for each occupation (i.e., a job exposure matrix). The latter method, while advanced, still has some important limitations, as highlighted in a review summarizing an expert panel’s findings by Kheifets et al. (2009).<sup>18</sup> While a person’s occupation may provide some indication of the overall magnitude of their occupational magnetic field exposure, it does not take into account the possible variation in exposure due to different job tasks within occupational titles, the frequency and intensity of contact to relevant exposure sources, or variation by calendar time. Furthermore, since scientists do not know any mechanism by which magnetic fields could lead to cancer, an appropriate exposure metric is unknown.

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<sup>18</sup> Kheifets et al. (2009) reports on the conclusions of an independent panel organized by the Energy Networks Association in the United Kingdom in 2006 to review the current status of the science on occupational EMF exposure and identify the highest priority research needs.

In order to reduce the remaining uncertainty about whether there is an association between magnetic fields and these cancers, researchers have recommended (1) meta-analyses to clarify inconsistencies and (2) better exposure assessment methods that incorporate a greater level of detail on tasks and exposure characteristics such as spark discharge, contact current, harmonics, etc. (WHO, 2007a; Kheifets et al., 2009).

### **Adult brain cancer**

#### **What was previously known about adult brain cancer and what did the WHO review conclude?**

As described above, the WHO classified the epidemiologic data on adult brain cancer as inadequate and recommended (1) updating the existing cohorts of occupationally-exposed individuals in Europe and (2) pooling the epidemiologic data on brain cancer and adult leukemia to confirm the absence of an association.<sup>19</sup>

#### **What relevant studies have been published since the WHO review?**

Epidemiologic studies published after 2006 on adult brain cancer and EMF exposure are listed in Table 6 and include two case-control studies, two cohort studies, and a meta-analysis, all of which are related to occupational magnetic field exposure.

In response to the WHO's recommendation, two cohorts of approximately 20,000 occupationally-exposed persons each were updated: a cohort of utility workers in Denmark and a cohort of railway workers in Switzerland (Johansen et al., 2007; Röösli et al., 2007a). In both cohorts, brain cancer rates were similar between jobs with high magnetic field exposure and jobs with lower exposures. A case-control study of gliomas was conducted in Australia and reported no associations with higher estimated magnetic field exposure, using a standard job-exposure matrix (Karipidis et al., 2007a). Forssén et al. (2006) performed a large registry-based case-control study of acoustic neuroma and reported no association between higher occupational magnetic field exposures and this benign and rare brain cancer type. Another large case-control study was recently published of gliomas and meningiomas in the United States (Coble et al.,

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<sup>19</sup> The WHO concluded, “In the case of adult brain cancer and leukaemia, the new studies published after the IARC monograph do not change the conclusion that the overall evidence for an association between ELF [EMF] and the risk of these disease remains inadequate” (p. 307, WHO 2007a).

2009). For the first time, the exposure metric in this study incorporated the frequency of exposure to EMF sources, as well as the distance people worked from these sources, on an individual basis. The authors also evaluated exposure metrics in addition to the time-weighted average (TWA) exposure (maximum exposed job, total years of exposure above 1.5 mG, cumulative lifetime exposure, and average lifetime exposure). No association was reported between any of these exposure metrics and brain cancer.

As recommended in the WHO review, a meta-analysis of occupationally-exposed cohorts was performed by Kheifets et al. (2008). All relevant publications of occupational EMF exposure and adult leukemia or brain cancer were collected and summary risk estimates were calculated using various schemes to weight and categorize the study data. The authors reported a small and statistically significant increase of leukemia and brain cancer in relation to the highest estimate of magnetic field exposure in the individual studies. Several findings, however, led the authors to conclude that magnetic field exposure is not responsible for the observed associations, including the lack of a consistent pattern among leukemia subtypes when the past and new meta-analyses were compared. In addition, for brain cancer, the recent meta-analysis reported a weaker association than the previous meta-analysis, whereas a stronger association would be expected since the quality of studies has increased over time. The authors concluded, “the lack of a clear pattern of EMF exposure and outcome risk does not support a hypothesis that these exposures are responsible for the observed excess risk” (p. 677).

Recent studies have reduced possible exposure misclassification by improving exposure assessment methods (i.e., the expanded job-exposure matrix in Coble et al., 2009) and attempted to clarify inconsistencies by updating studies and meta-analyzing data (Johansen et al., 2007; Röösli et al., 2007a; Kheifets et al., 2008); however, despite these advancements, no association has been observed. While an association still cannot be *entirely* ruled out because of the remaining deficiencies in exposure assessment methods, the current database of studies provides

weak evidence of an association between magnetic fields and brain cancer.<sup>20</sup> The recent report by the SCENIHR described the data on brain cancers as “uncertain” (p. 43, SCENIHR 2009).

**Table 4. Relevant studies of adult brain cancer published after WHO review**

Authors	Year	Study
Coble et al.	2009	Occupational exposure to magnetic fields and the risk of brain tumors
Forssén et al.	2006	Occupational magnetic field exposure and the risk of acoustic neuroma
Johansen et al.	2007	Risk for leukaemia and brain and breast cancer among Danish utility workers: A second follow-up
Karipidis et al.	2007a	Occupational exposure to low frequency magnetic fields and the risk of low grade and high grade glioma
Kheifets et al.	2008	Occupational electromagnetic fields and leukemia and brain cancer: An update to two meta-analyses
Röösli et al.	2007a	Leukaemia, brain tumours and exposure to extremely low frequency magnetic fields: cohort study of Swiss railway employees

### **Adult leukemia and lymphoma**

#### **What was previously known about adult leukemia/lymphoma and what did the WHO review conclude?**

The same issues discussed above with regard to adult brain cancer are relevant to research on adult leukemia and lymphoma. The WHO classified the epidemiologic evidence as “inadequate” and recommended updating the existing occupationally-exposed cohorts in Europe and the meta-analysis on occupational magnetic field exposure (p. 307, WHO 2007a).<sup>21</sup>

#### **What relevant studies have been published since the WHO review?**

Two cohorts of occupationally-exposed workers and a meta-analysis of occupational magnetic field exposure (all of which were described above) reported on the possible association of occupational magnetic field exposure and adult leukemia. Also, a case-control study described patterns of estimated residential magnetic field exposure and combined lymphoma and leukemia diagnostic categories (Lowenthal et al., 2007).

<sup>20</sup> A recent consensus statement by the National Cancer Institute’s Brain Tumor Epidemiology Consortium confirms this statement. They classified residential power frequency EMF in the category “probably not risk factors” and described the epidemiologic data as “unresolved” (p. 1958, Bondy et al., 2008).

<sup>21</sup> No specific conclusions were provided by the WHO with regard to lymphoma.

In the occupational cohort of Swiss railway workers, the authors noted a stronger association among occupations with higher estimates of magnetic field exposures, but the associations were not statistically significant (Röösli et al, 2007a). In the study of Danish utility workers, no increases in leukemia rates were observed in job titles that involved higher exposures to magnetic fields (Johansen et al., 2007). As described above, the updated meta-analysis by Kheifets et al. (2008) reported a weak association between estimated occupational magnetic field exposure and leukemia, but the authors felt that the data was not indicative of a true association.

Lowenthal et al. (2007) grouped cases in five diagnostic categories as lymphoproliferative disorders (LPD) (including acute lymphoblastic leukemia [ALL]) and cases in three diagnostic categories (including acute myeloid leukemia [AML] and other leukemias) as myeloproliferative disorders (MPD). These groups included both adults and children of all ages. The authors estimated exposure by obtaining a lifetime residential history and assessing distance of residences from 88-kV, 110-kV, and 220-kV power lines. They reported elevated, but not statistically significant, ORs for those who lived within 50 m of any of these power lines, and an indication of decreasing ORs with increasing distance. This study adds very little to the existing database of information on adult leukemia and residential exposure, however, because of fundamental limitations. For example, different cancer types were combined as were different ages of diagnosis. It is well known that cancer etiology varies by cancer type, cancer subtype, and diagnostic age.<sup>22</sup>

Very little is known about the etiology of Non-Hodgkin lymphoma (NHL), and few studies have been conducted in relation to magnetic field exposure. In one of the first studies to estimate cumulative occupational magnetic field exposure among NHL cases, Karipidis et al. (2007b) reported a statistically significant association between NHL and the highest category of exposure (OR=1.59, 95% CI=1.07-2.36). Overall, the study was well conducted, with its most significant limitation being the possibility of uncontrolled confounding. In another case-control study of NHL, Wong et al. (2010) identified 649 cases from a hospital in Shanghai. Among numerous questions in the interview, cases and controls were asked whether they had ever lived

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<sup>22</sup> The recent meta-analysis by Kheifets et al. (2010) implies that data are available from Lowenthal et al. (2007) for childhood leukemia as a separate diagnostic category. This information is not publicly accessible, however.

within 100 m of a high-voltage power line. Results showed no association (i.e., no differences in residential history between cases and controls), but the strength of the study is limited by the use of distance as a proxy for exposure. Another recent case-control study did not report an association between NHL and self-report of occupations likely to involve EMF exposure derived from a JEM (Richardson et al., 2008).

Of note, the cohort of railway workers in Switzerland did not report an increase in NHL deaths among the more highly exposed workers (Röösli et al, 2007a). Further research in this area is required.

The recent literature also includes a novel study examining whether there are differences in the activity of the natural killer (NK) cell, a cytotoxic immune cell which attacks tumor cells and cells infected with viruses, among persons occupationally exposed to magnetic fields (Gobba et al., 2008). Higher measured magnetic field levels (i.e., >10 mG) during three complete work shifts were associated with reduced NK activity. Future studies are required to replicate this finding and understand the potential significance of NK activity in cancer.

A number of studies of adult leukemia have attempted to clarify inconsistencies by updating studies and meta-analyzing data (Johansen et al., 2007; Kheifets et al., 2008; Röösli et al, 2007a); however, despite these advancements, no clear or statistically significant association has been observed. While an association still cannot be *entirely* ruled out because of the remaining deficiencies in exposure assessment methods, the current database of studies provides weak evidence of an association between magnetic fields and leukemia. Preliminary results related to NHL have been published and require further investigation.

**Table 5. Relevant studies of adult leukemia/lymphoma published after the WHO review**

<b>Authors</b>	<b>Year</b>	<b>Study</b>
Gobba et al.	2008	Extremely low frequency-magnetic fields (ELF-EMF) occupational exposure and natural killer activity in peripheral blood lymphocytes
Johansen et al.	2007	Risk for leukaemia and brain and breast cancer among Danish utility workers: A second follow-up
Karipidis et al.	2007b	Occupational exposure to power frequency magnetic fields and risk of non-Hodgkin lymphoma
Kheifets et al.	2008	Occupational electromagnetic fields and leukemia and brain cancer: An update to two meta-analyses
Lowenthal et al.	2007	Residential exposure to electric power transmission lines and risk of lymphoproliferative and myeloproliferative disorders: a case-control study
Richardson et al.	2008	Occupational risk factors for non-Hodgkin's lymphoma: a population-based case-control study in northern Germany
Röösli et al.	2007a	Leukaemia, brain tumours and exposure to extremely low frequency magnetic fields: cohort study of Swiss railway employees
Wong et al.	2010	A hospital-based case-control study of non-Hodgkin lymphoid neoplasms in Shanghai: Analysis of personal characteristics, lifestyle, and environmental risk factors by subtypes of the WHO classification

### ***In vivo studies of carcinogenesis***

#### **What was previously known about *in vivo* studies of carcinogenesis and what did the WHO review conclude?**

It is standard procedure to conduct studies on laboratory animals to determine whether exposure to a specific agent leads to the development of cancer (USEPA, 2005). This approach is used because all known human carcinogens cause cancer in laboratory animals. In the field of ELF EMF research, a number of research laboratories have exposed rodents, including those with a particular genetic susceptibility to cancer, to high levels of magnetic fields over the course of the animals' lifetime and performed tissue evaluations to assess the incidence of cancer in many organs. In these studies, magnetic field exposure has been administered alone (to test for the ability of magnetic fields to act as a complete carcinogen), in combination with a known carcinogen (to test for a promotional or co-carcinogenic effect), or in combination with a known carcinogen and a known promoter (to test for a co-promotional effect).

The WHO review described four large-scale, long-term studies of rodents exposed to magnetic fields over the course of their lifetime that did not report increases in any type of cancer (Mandeville et al., 1997; Yasui et al., 1997; Boorman et al., 1999a, 1999b; McCormick et al., 1999). No directly relevant animal model for childhood ALL existed at the time of the WHO

report. Some animals, however, develop a type of lymphoma similar to childhood ALL and studies exposing predisposed transgenic mice to ELF magnetic fields did not report an increased incidence of lymphoma (Harris et al., 1998; McCormick et al., 1998; Sommer and Lerchel, 2004).

Studies investigating whether exposure to magnetic fields can promote cancer or act as a co-carcinogen used known cancer-causing agents, such as ionizing radiation, ultraviolet radiation, or other chemicals. No effects were observed for studies on chemically-induced preneoplastic liver lesions, leukemia or lymphoma, skin tumors, or brain tumors; however, the incidence of 7,12-dimethylbenz[a]anthracene (DMBA)-induced mammary tumors was increased with magnetic field exposure in a series of experiments in Germany (Löscher et al., 1993, 1994, 1997; Baum et al., 1995; Löscher and Mevissen, 1995; Mevissen et al., 1993a, 1993b, 1996a, 1996b, 1998), suggesting that magnetic field exposure increased the proliferation of mammary tumor cells. These results were not replicated in a subsequent series of experiments in a laboratory in the United States (Anderson et al., 1999; Boorman et al. 1999a, 1999b), possibly due to differences in experimental protocol and the species strain. In Fedrowitz et al. (2004), exposure enhanced mammary tumor development in one sub-strain (Fischer 344 rats), but not in another sub-strain that was obtained from the same breeder, which argues against a promotional effect of magnetic fields.<sup>23</sup>

Some studies have reported an increase in genotoxic effects among exposed animals (e.g., DNA strand breaks in the brains of mice [Lai and Singh, 2004]), although the results have not been replicated.

In summary, the WHO concluded the following with respect to *in vivo* research: “There is no evidence that ELF exposure alone causes tumours. The evidence that ELF field exposure can enhance tumour development in combination with carcinogens is inadequate” (p. 322, WHO 2007a). Recommendations for future research included the development of a rodent model for childhood ALL and the continued investigation of whether magnetic fields can act as a promoter or co-carcinogen.

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<sup>23</sup> The WHO concluded with respect to the German studies of mammary carcinogenesis, “Inconsistent results were obtained that may be due in whole or in part to differences in experimental protocols, such as the use of specific substrains” (p. 321, WHO 2007a).

### What relevant studies have been published since the WHO review?

In view of the available evidence that exposure to magnetic fields *alone* does not increase the occurrence of cancer, the literature published following the WHO review includes numerous *in vivo* studies testing different hypotheses of cancer promotion, including effects on brain cancer (Chung et al., 2008), breast cancer (Fedrowitz and Löscher, 2008), and lymphoma or leukemia (Bernard et al., 2008; Negishi et al., 2008; Chung et al., 2010), as referenced below. Studies of genotoxicity and oxidative damage *in vivo* have also been published since 2006, but these studies are just conceptually linked to carcinogenicity; this summary focuses on studies of tumor progression since these studies are the most relevant. In most of these studies, the animals were treated first with chemicals known to initiate the cancer process. Initiated animals are more likely to develop cancer, and a subsequent exposure, known as a promoter, is often needed for an initiated cell to reproduce into many cancer cells. Several studies treated the animals with the initiators ethylnitrosourea (ENU) (Chung et al., 2008), n-butylnitrosourea (BNU) (Bernard et al., 2008), and DMBA (Fedrowitz and Löscher, 2008; Negishi et al., 2008). In Chung et al. (2010), mice that are genetically predisposed to develop thymic lymphoblastic lymphoma were exposed to magnetic fields to assess whether such exposure increased incidence of lymphoma or reduced survival. An additional study by Sommer and Lerchel (2006) tested whether magnetic fields alone increased the incidence of lymphoma in mice virally predisposed to lymphoblastic lymphoma.

Chung et al. (2008) examined the possible role of 60-Hz magnetic fields in promoting brain tumors initiated by ENU injections *in utero*; the authors concluded that there was no evidence that exposure to 60-Hz magnetic fields up to 5,000 mG promoted tumor development in this study.

Fedrowitz and Löscher (2008) is the most recent study from the German laboratory that previously reported increases in DMBA-induced mammary tumors with high magnetic field exposure. In this recent study, the researchers exposed DMBA-treated Fischer 344 rats (the strain of inbred rats used in previous experiments) to either high levels of magnetic fields (1,000 mG) or no exposure for 26 weeks and reported that the incidence of mammary tumors was significantly elevated in the group exposed to magnetic fields (Fedrowitz and Löscher, 2008).

No independent replication of this experiment has yet occurred and questions still remain about the effect of experimental protocol and species strain.

Sommer and Lerchl (2006) is a follow-up to an earlier study (Sommer and Lerchl, 2004) that reported no increases in lymphoma among predisposed animals chronically exposed to magnetic fields (up to 1,000 mG for 24 hours per day for 32 weeks). Sommer and Lerchl (2006) increased magnetic field exposure to 10,000 mG and exposed some of the animals only during the night to test the hypothesis that nighttime exposure may have a stronger effect than continuous exposure. Magnetic fields did not influence body weight, time to tumor, cancer incidence, or survival time in this study. In another study of lymphatic system cancers, researchers treated newborn mice with DMBA and magnetic fields up to 3,500 mG (Negishi et al., 2008). The authors reported that the percentage of mice with lymphoma or lymphatic leukemia was not higher in magnetic field-exposed groups, compared to the sham-exposed group.

In another study of lymphoid leukemia, Chung et al (2010) evaluated the effect of magnetic fields on AKR mice, which are genetically predisposed to thymic lymphoblastic lymphoma. Exposures ranged from 50-500 mG for 21 hours per day for 40 weeks, and cancer incidence was compared with a sham-exposed control group. Potential confounding variables (such as temperature, humidity, and magnetic-field variations) were monitored daily. The experiment was performed blind to ensure that biases were not introduced by investigator knowledge of exposure conditions. Magnetic-field exposures were not associated with changes in body weight, survival time, or the incidence of lymphoma compared to sham-treated controls. Exposure also did not affect components of the blood, micronuclei formation, or gene expression in the thymus.

A study by Bernard et al. (2008) provides a significant development, in that it is the first study to use an animal model of ALL, the most common leukemia type in children. All rats were exposed to BNU to initiate the leukemogenic process, and a sub-group of rats was exposed to magnetic fields of 1,000 mG for 18 hours per day for 52 weeks. No difference in leukemia incidence was observed between the BNU-treated group exposed to magnetic fields and the BNU-treated unexposed group. This study supports the hypothesis that magnetic fields do not

affect the development of ALL and provides additional support to the conclusion that experimental data is not supportive for a role of magnetic fields in the incidence of childhood leukemia. The researchers followed guidelines for the experimentation and care of laboratory animals and conducted the analyses blind to the treatment group. Experience with this strain of rat is limited, however, so it is unclear whether the results are more or less reliable than other animal models; replication is required.

Thus, aside from the most recent replication of enhanced mammary carcinogenesis in a specific sub-strain of rats in a German laboratory, recent studies provide further evidence against a role for magnetic fields as a co-carcinogen. These studies strengthen the conclusion that there is inadequate evidence of carcinogenicity from *in vivo* research, although independent confirmation of the German results is of high priority.

**Table 6. Relevant *in vivo* studies of carcinogenesis published after the WHO review**

Authors	Year	Study
Bernard et al.	2008	Assessing the potential Leukemogenic effects of 50 Hz and their harmonics using an animal leukemia model
Chung et al.	2008	Lack of a co-promotion effect of 60 Hz rotating magnetic fields on n-ethyl-n-nitrosourea induced neurogenic tumors in F344 rats
Chung et al.	2010	Lack of co-promotion effect of 60 Hz circularly polarized magnetic fields on spontaneous development of lymphoma in AKR mice
Fedrowitz and Löscher	2008	Exposure of Fischer 344 rats to a weak power frequency magnetic field facilitates mammary tumorigenesis in the DMBA model of breast cancer
Negishi et al.	2008	Lack of promotion effects of 50 Hz magnetic fields on 7,12-dimethylbenz(a)anthracene-induced malignant lymphoma/lymphatic leukemia in mice
Sommer and Lerchl	2006	50 Hz magnetic fields of 1 mT do not promote lymphoma development in AKR/J mice

### ***In vitro* studies of carcinogenesis**

#### **What did the WHO and other scientific panels conclude with respect to *in vitro* studies of carcinogenesis?**

*In vitro* studies are widely used to investigate the mechanisms for effects that are observed in humans and animals. The relative value of *in vitro* tests to human health risk assessment, however, is much less than that of *in vivo* and epidemiology studies. Responses of cells and tissues outside the body may not always reflect the response of those same cells if maintained in a living system, so the relevance of *in vitro* studies cannot be assumed (IARC, 1992).

The IARC and other scientific review panels that systematically evaluated *in vitro* studies concluded that there is no clear evidence indicating how ELF magnetic fields could adversely affect biological processes in cells (IARC, 2002; ICNIRP, 2003; NRPB, 2004). The WHO panel reviewed the *in vitro* research published since the time of these reviews and reached the same conclusion. The WHO noted that previous studies have not indicated a genotoxic effect of ELF magnetic fields on mammalian cells, however a series of experiments reported DNA damage in human fibroblasts exposed intermittently to 50 Hz magnetic fields (Ivancsits et al., 2002a, 2002b; Ivancsits et al., 2003a, 2003b). These findings have not been replicated by other laboratories (Scarfì et al., 2005), and the WHO recommended continued research in this area. Recently, investigators reported that they were unable to confirm any evidence for damage to DNA in cells exposed to magnetic fields over a range of exposures from 50 to 10,000 mG (Burdak-Rothkamm et al., 2009). Research in the field of *in vitro* genotoxicity of magnetic fields combined with known DNA-damaging agents is also recommended, following suggestive findings from several laboratories. As noted by the SSI, however, the levels at which these effects were observed are much higher than the levels to which we are exposed in our everyday environments and are, therefore, not directly relevant to questions about low-level, chronic exposures (SSI, 2007). *In vitro* studies investigating other possible mechanisms, including gene activation, cell proliferation, apoptosis, calcium signaling, intercellular communication, heat shock protein expression, and malignant transformation have produced “inconsistent and inconclusive” results, according to the WHO (p. 347, WHO, 2007a).

## **Reproductive and developmental effects**

### **What was previously known about reproductive and developmental effects and what did the WHO review conclude?**

Two studies received considerable attention because of a reported association between peak magnetic field exposure greater than approximately 16 mG and miscarriage: a prospective cohort study of women in early pregnancy (Li et al., 2002) and a nested case-control study of women who miscarried compared to their late-pregnancy counterparts (Lee et al., 2002).

These two studies improved on the existing body of literature because average exposure was assessed using 24-hour personal magnetic field measurements (early studies on miscarriage

were limited because they used surrogate measures of exposure, including visual display terminal use, electric blanket use, or wire code data). Following the publication of these two studies, however, a hypothesis was put forth that the observed association may be the result of behavioral differences between women with “healthy” pregnancies that went to term (less physically active) and women who miscarried (more physically active) (Savitz, 2002). It was proposed that physical activity is associated with an increased opportunity for peak magnetic field exposures, and the nausea experienced in early, healthy pregnancies and the cumbersomeness of late, healthy pregnancies would reduce physical activity levels, thereby decreasing the opportunity for exposure to peak magnetic fields. Furthermore, nearly half of the miscarriages reported in the cohort by Li et al. had magnetic field measurements taken after miscarriage occurred, when changes in physical activity may have already occurred, and all measurements in Lee et al. occurred post-miscarriage.

The scientific panels that have considered these two studies concluded that the possibility of this bias precludes making any conclusions about the effect of magnetic fields on miscarriage (NRPB, 2004; FPTRPC, 2005; WHO, 2007a). The WHO concluded, “There is some evidence for increased risk of miscarriage associated with measured maternal magnetic field exposure, but this evidence is inadequate” (p. 254, WHO 2007a). The WHO stated that, given the potentially high public health impact of such an association, further epidemiologic research is recommended.

### **What relevant studies have been published since the WHO review?**

No new original studies on magnetic field exposure and miscarriage have been conducted; however, recent methodological studies evaluated the likelihood that the observed association was due to bias. Epidemiologic and *in vivo* studies of ELF EMF and reproductive and developmental effects are summarized in Table 7.

It is not possible to directly “test” for the effects of this bias in the original studies, but two recent analyses examined whether reduced physical activity was associated with a lower probability of encountering peak magnetic fields (Mezei et al., 2006; Savitz et al., 2006). In a 7-day study of personal magnetic field measurements in 100 pregnant women, Savitz et al. (2006)

reported that active pregnant women were more likely to encounter peak magnetic fields. In addition, an analysis by Mezei et al. (2006) of pre-existing databases of magnetic field measurements among pregnant and non-pregnant women found that increased activity levels were associated with peak magnetic fields. These findings are broadly supportive of the hypothesis that reduced activity among women in early pregnancies because of nausea and in later pregnancies because of cumbersoness may explain the observed association between peak magnetic fields and miscarriage. As noted in a recent commentary on this issue, however, the possibility that there is a relationship between peak magnetic field exposure and miscarriage still cannot be excluded and further research that accounts for this possible bias should be conducted (Neutra and Li, 2008; Mezei et al., 2006). There remains no biological basis, however, to indicate that magnetic field exposure increases the risk of miscarriage (WHO, 2007a).

Two additional studies were published related to developmental outcomes and growth. Fadel et al. (2006) conducted a cross-sectional study in Egypt of 390 children 0-12 years of age living in an area within 50 m of an electrical power line and 390 children 0-12 years of age living in a region with no power lines in close proximity. Measurements were taken as proxies of growth retardation, and radiological assessments were performed on carpal bones. The authors reported that children living in the region near power lines had a statistically significant lower weight at birth and a reduced head and chest circumference and height at all ages. The authors concluded that “exposure to low frequency electromagnetic fields emerged [sic] from high voltage electric power lines increases the incidence of growth retardation among children” (p. 211). This conclusion, however, fails to adequately take into account the many limitations of their cross-sectional analysis (namely, inadequate control for the possible confounding effects of nutritional and SES status) and the pre-existing body of literature, which does not support such an association (WHO, 2007a). Public health statistics indicate that detrimental birth outcomes, including pre-term birth, low birth weight, or small for gestational age, occur more frequently in populations of lower SES (HHS, 2004); thus, analyses of adverse birth outcomes should be adjusted for these factors.

Auger et al. (2010) studied whether maternal residence near transmission lines was associated with adverse birth outcomes, adjusting for socioeconomic factors, among all live births in

Montreal and Canada between 1990 and 2004. Maternal residential distances were measured within 400 m of nearby transmission lines for over 700,000 live births, and the proportion of adverse events was compared between mothers living >400 m and within 400 m, adjusting for mother's age, education, household income, and other potential confounding factors. The analysis found no association with distances in 50 m increments for any of the outcomes: pre-term birth, low birth weight, small for gestational age, or proportion of male births. The use of distance as a surrogate of EMF exposure limits the value of this study.

Among recent *in vivo* reproductive studies of ELF EMF, seven examined effects on the female reproductive system (Aksen et al., 2006; Roushanger and Soleimani Rad, 2007; Al-Akhras et al., 2008; Anselmo et al., 2009; Aydin et al., 2009; De Bruyen and De Jager, 2010; Rajaei et al., 2010). In most of these studies, the researchers did not clarify whether they incorporated blinding to minimize bias and failed to indicate whether they used appropriate statistical analyses (e.g., use of the litter, rather than the pup, as the unit for analysis since littermates are known to be more similar to each other than offspring derived from separate litters). Other limitations included the use of animals with extremely deficient diets and the use of only one magnetic field level so that dose-response could not be assessed. Although some of the studies reported biological changes, none of the studies reported strong evidence of adverse reproductive outcomes.

Studies of reproductive effects on males were conducted across a broad range of exposures and duration and reported various responses of the male reproductive and accessory sex organs, as well as alterations in sex hormone concentrations (Akdag et al., 2006; Al-Akhras et al., 2006; Mostafa et al., 2006; Saad El-Din et al., 2006; Erpek et al., 2007; Farkhad et al., 2007; Khaki et al., 2008; Geng et al., 2009; Kim et al., 2009; Rajaei et al., 2009; Bernabo et al., 2010; De Bruyn and de Jager, 2010). These studies also suffered from flaws that affect validity; most failed to report methods to ensure blinding, few studies examined dose-response patterns, and some used only short-term exposures to extremely high fields. In a study involving exposure to two generations of mice, De Bruyn and de Jager (2010) reported decreases in sperm motility; however, these did not translate to functional decrements in reproductive capacity. Although these studies suggest possible male reproductive system alterations from EMF exposure, the

evidence is not strong and no firm conclusions can be drawn due to the conflicting nature of the reported responses.

Studies also were conducted of exposure during pregnancy (Anselmo et al., 2006, 2008; Okudan et al., 2006; Yao et al., 2007; Dundar et al., 2009; De Bruyn and De Jager, 2010). The studies entailed high and short-term exposures and had specific and narrow goals, e.g., evaluating changes in the eye or bone. Of note, De Bruyn and De Jager (2010) continuously exposed mice to a randomly varying 50-Hz magnetic field between 5 mG and 770 mG from conception through two generations of offspring in a double-blind study. Both the treated and sham-exposed groups consisted of ten pairs of mice in each generation. No effects of exposure were observed on mean gestational and generational days, mean litter size, or total number of stillborn pups. Like the other studies, however, the authors did not indicate whether appropriate statistical methods were used to control for potential litter effects.

Thus, the recent epidemiologic research does not provide sufficient evidence to alter the conclusion that the evidence for reproductive or developmental effects is inadequate. Recent studies of animals *in vivo* also do not provide evidence to change the conclusions expressed by the WHO. Various deficiencies in the methods and reporting of these studies limit their use in health risk assessment.

**Table 7. Relevant studies of reproductive and developmental effects published after the WHO review**

Authors	Year	Study
Akdag et al.	2006	Effect of ELF magnetic fields on lipid peroxidation, sperm count, p53 and trace elements
Aksen et al.	2006	Effect of 50-Hz 1-mT magnetic field on the uterus and ovaries of rats (electron microscopy evaluation)
Al-Akhras et al.	2006	Influence of 50 Hz magnetic field on sex hormones and other fertility parameters of adult male rats
Al-Akhras et al.	2008	Influence of 50 Hz magnetic field on sex hormones and body, uterine, and ovarian weights of adult female rats
Anselmo et al.	2006	Influence of a 60 Hz, 3 microT, electromagnetic field on the reflex maturation of Wistar rats offspring from mothers fed a regional basic diet during pregnancy
Anselmo et al.	2008	Influence of a 60 Hz, microT, electromagnetic field on the somatic maturation of wistar rat offspring fed a regional basic diet during pregnancy
Anselmo et al.	2009	Effects of the electromagnetic field, 60 Hz, 3 microT, on the hormonal and metabolic regulation of undernourished pregnant rats

Authors	Year	Study
Auger et al.	2010	The relationship between residential proximity to extremely low frequency power transmission lines and adverse birth outcomes
Aydin et al.	2009	Evaluation of hormonal change, biochemical parameters, and histopathological status of uterus in rats exposed to 50-Hz electromagnetic field
Bernabó et al.	2010	Extremely low frequency electromagnetic field exposure affects fertilization outcome in swine animal model
De Bruyen and De Jager	2010	Effect of long-term exposure to a randomly varied 50 Hz power frequency magnetic field on the fertility of the mouse
Dundar et al.	2009	The effect of the prenatal and post-natal long-term exposure to 50 Hz electric field on growth, pubertal development and IGF-1 levels in female Wistar rats
Erpek et al.	2007	The effects of low frequency electric field in rat testis
Fadel et al.	2006	Growth assessment of children exposed to low frequency electromagnetic fields at the Abu Sultan area in Ismailia (Egypt)
Farkhad et al.	2007	Effects of extremely low frequency electromagnetic field on testes in guinea pig
Geng et al.	2009	Effects of electromagnetic field of UHV transmission lines exposure on testis tissue in mice
Khaki et al.	2008	The effects of electromagnetic field on the microstructure of seminal vesicles in rat: a light and transmission electron microscope study
Kim et al.	2009	Effects of 60 Hz 14 $\mu$ T magnetic field on the apoptosis of testicular germ cell in mice
Mezei et al.	2006	Analyses of magnetic-field peak-exposure summary measures
Mostafa et al	2006	Sex hormone status in male rats after exposure to 50 Hz, mT magnetic field
Neutra and Li	2008	Letter to the Editor – Magnetic fields and miscarriage: A commentary on Mezei et al., JESEE 2006
Okudan et al.	2006	DEXA analysis on the bones of rats exposed in utero and neonatally to static and 50 Hz electric fields
Rajaei et al.	2009	Effects of extremely low-frequency magnetic field on mouse epididymis and deferens ducts
Rajaei et al.	2010	Effects of extremely low-frequency electromagnetic field on fertility and heights of epithelial cells in pre-implantation stage, endometrium and fallopian tube in mice
Roushanger and Soleimani Rad	2007	Ultrastructural alterations an occurrence of apoptosis in developing follicles exposed to low frequency electromagnetic field in rat ovary
Saad El-Din et al.	2006	Evaluation of the structural changes of extremely low frequency electromagnetic fields on brain and testes of adult male mice
Savitz et al.	2006	Physical activity and magnetic field exposure in pregnancy
Yao et al.	2007	Absence of effect of power-frequency magnetic fields on exposure on mouse embryonic lens development

## Neurodegenerative disease

### What was previously known about neurodegenerative disease and what did the WHO review conclude?

Research into the possible effect of magnetic fields on the development of neurodegenerative diseases began in 1995, and the majority of research since then has focused on Alzheimer's disease and a specific type of motor neuron disease called amyotrophic lateral sclerosis (ALS), which is also known as Lou Gehrig's disease. The inconsistency of early Alzheimer's disease studies prompted the NRPB to conclude that there is "only weak evidence to suggest that it [ELF magnetic fields] could cause Alzheimer's disease" (p. 20, NRPB, 2001). Early studies on ALS, which had no obvious biases and were well conducted, reported an association between ALS mortality and estimated occupational magnetic field exposure. The review panels, however, were hesitant to conclude that the associations provided strong support for a causal relationship. Rather, they felt that an alternative explanation (i.e., electric shocks received at work) may be the source of the observed association.

The majority of the more recent studies discussed by the WHO reported statistically significant associations between occupational magnetic field exposure and mortality from Alzheimer's disease and ALS, although the design and methods of these studies were relatively weak (e.g., disease status was based on death certificate data, exposure was based on incomplete occupational information from census data, and there was no control for confounding factors). Furthermore, there was no biological data to support an association between magnetic fields and neurodegenerative diseases. The WHO panel concluded that there is "inadequate" data in support of an association between magnetic fields and Alzheimer's disease or ALS.<sup>24</sup> The panel recommended more research in this area using better methods; in particular, studies that enrolled incident Alzheimer's disease cases (rather than ascertaining cases from death certificates) and studies that estimated electrical shock history in ALS cases were recommended.

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<sup>24</sup> After considering the entire body of literature and its limitations, the WHO report concluded, "When evaluated across all the studies, there is only very limited evidence of an association between estimated ELF exposure and [Alzheimer's] disease risk" (p. 194, WHO 2007a).

### What relevant studies have been published since the WHO review?

Six studies have been published since the WHO review. Two occupational cohorts were followed for neurodegenerative diseases—approximately 20,000 railroad workers in Switzerland (Röösli et al., 2007b) and over 80,000 electrical and generation workers in the United Kingdom (Sorahan and Kheifets, 2007). Two case-control studies collected incident cases of Alzheimer's disease and estimated occupational magnetic field exposure (Davanipour et al., 2007; Seidler et al., 2007), and a meta-analysis was conducted of occupational magnetic field exposure and Alzheimer's disease studies (García et al., 2008). The first study of non-occupational exposure followed the Swiss population to evaluate associations with residential distance to power lines and death due to neurodegenerative diseases (Huss et al., 2009).

García et al. (2008) identified 14 epidemiologic studies with information on Alzheimer's disease and occupational EMF exposure; the WHO considered the majority of these studies in their 2007 review. A statistically significant association between Alzheimer's disease and occupational EMF exposure was observed for both case-control and cohort studies ( $OR = 2.03$ , 95% CI=1.38-3.00 and  $RR = 1.62$ , 95% CI=1.16-2.27, respectively), although the results from the individual studies were so different that the authors cautioned against the validity of these combined results. While some subgroup analyses had statistically significant increased risks and were not significantly heterogeneous between studies, the findings were contradictory between study design types (e.g., elevated pooled risk estimates were reported for *men* in cohort studies and elevated pooled risk estimates were reported for *women* in case-control studies). The authors concluded that their results suggest an association between Alzheimer's disease and occupational magnetic field exposure, but noted the numerous limitations associated with these studies, including the difficulty of assessing EMF exposure during the appropriate time period, case ascertainment issues due to diagnostic difficulties, and differences in control selection. They recommended further research that uses more advanced methods.

An earlier publication by the same group of investigators documented the relatively poor quality of the studies included in the meta-analysis. Santibáñez et al. (2007) evaluated studies related to occupational exposure and Alzheimer's disease, which included seven of the studies in the García et al. meta-analysis. Two epidemiologists blindly evaluated each of these studies using a

questionnaire to assess the possibility of a number of biases, with a score assigned to each study that represented the percentage of possible points that the study obtained (range 0-100%). Only one of the seven studies obtained a score above 50% (a retrospective cohort study by Savitz et al. in 1998), and disease and exposure misclassifications were the most prevalent biases.

Davanipour et al. (2007) extended an earlier hypothesis-generating study by Sobel et al. (1996) by collecting cases from eight California Alzheimer's Disease Diagnostic and Treatment Centers. Self-reported primary occupation was collected from patients with verified diagnoses of Alzheimer's disease and compared to occupational information collected from persons diagnosed with other dementia-related problems at the Centers. The results of this study were consistent with the previous studies by Sobel et al.; cases were approximately twice as likely to be classified as having medium/high magnetic field exposures, compared with controls. The strengths of this study included its large size and self-reported occupational information. The main limitation of this study was that the exposure assessment only considered a person's primary occupation, classified as low, medium, or high magnetic field exposure. The WHO noted limitations of the 1996 publication that are relevant to this publication as well, including the use of controls with dementia (which some studies report have an increased risk of Alzheimer's disease) and the classification of seamstresses, dressmakers, and tailors as "high exposure" occupations, which drives the increase in risk.

Seidler et al. (2007) conducted a similar case-control study in Germany, except cases included all types of dementia (55% of which had Alzheimer's disease). Cumulative magnetic field exposure was estimated from occupational histories taken from proxy respondents, and no difference was reported between cases of dementia or probable Alzheimer's disease and controls, although an association was reported among electrical and electronics workers. The authors reported that exposure misclassification was likely to be a significant problem and concluded that their results indicate a strong effect of low-dose EMF is "rather improbable" (p. 114).

Sorahan and Kheifets (2007) followed a cohort of approximately 84,000 electrical and generation workers in the United Kingdom for deaths attributed to neurodegenerative disease on death certificates. Cumulative magnetic field exposure was calculated for each worker, using

job and facility information. The authors reported that the cohort did not have a significantly greater number of deaths due to Alzheimer's disease or motor neuron disease compared to the general population in the United Kingdom. They also reported that persons with higher estimated magnetic field exposures did not have a consistent excess of death due to Alzheimer's disease or motor neuron disease compared to persons with lower estimated magnetic field exposure. A statistically significant excess of deaths due to Parkinson's disease was observed in the cohort, although there was no association between calculated magnetic field exposure and Parkinson's disease. The authors concluded "our results provide no convincing evidence for an association between occupational exposure to magnetic fields and neurodegenerative disease" (p. 14). This result is consistent with two other Alzheimer's mortality follow-up studies of electric utility workers in the United States (Savitz et al., 1998) and Denmark (Johansen and Olsen, 1998). The findings may be limited by the use of death certificate data, but are strengthened by the detailed exposure assessment.

Death from several neurodegenerative conditions was also evaluated in the cohort of more than 20,000 Swiss railway workers described above (Röösli et al., 2007b). Magnetic field exposure was characterized by specific job titles as recorded in employment records; stationmasters were considered to be in the lowest exposure category and were, therefore, used as the reference group. Train drivers were considered to have the highest exposure, and shunting yard engineers and train attendants were considered to have exposure intermediate to stationmasters and train drivers. Cumulative magnetic field exposure was also estimated for each occupation using on-site measurements and modeling of past exposures. The authors reported an excess of senile dementia disease among train drivers, compared to station masters, however, the difference was not statistically significant. The association was larger when restricted to Alzheimer's disease, but was still not statistically significant (hazard ratio [HR]=3.15, 95% CI=0.90-11.04); an association was observed between cumulative magnetic field exposure and Alzheimer's disease/senile dementia. No elevation in mortality was reported for multiple sclerosis, Parkinson's disease, or ALS among train drivers, shunting yard engineers, or train attendants, compared with stationmasters, nor were more deaths from these causes observed for higher estimated magnetic field exposures. Similar to another recent Swedish study (Feychtung et al., 2003), the authors reported that recent exposure was more strongly associated with Alzheimer's disease than past exposure.

There are several strengths of this study relative to the existing body of data. First, there is little turnover among Swiss railway employees, which means that study participants are enrolled in the cohort and possibly exposed for long periods of time. The wide variation in exposure levels between different occupations in the same industry allows for comparison of similar workers with different levels of exposure. Another advantage is that the company kept detailed registers of employees, which means there is less potential for bias in the enumeration of the cohort and reconstruction of exposures. Finally, the authors reported that exposures to chemicals or electric shocks, which often occur in other occupational settings (for example, in electric utility workers or welders), are rare in this occupation.

Another cohort study conducted in Switzerland linked all persons older than 30 years of age at the 2000 census with a national database of death certificates from 2000 through 2005 (Huss et al., 2009). Residential location was also extracted from 1990 and 2000 census data and the closest distance of a person's home in 2000 to nearby 220-380 kV transmission lines was calculated. The authors reported that persons living within 50 m of these high-voltage transmission lines were more likely to have died from Alzheimer's disease, compared to those living farther than 600 m, although chance could not be ruled out as an explanation ( $HR=1.24$ , 95% CI=0.80-1.92). The association was stronger for persons that lived at the residence for at least 15 years ( $HR=2.00$ , 95% CI=1.21-3.33). Associations of similar magnitude were reported for senile dementia and residence within 50 m of a high-voltage line. No associations were reported beyond 50 m for Alzheimer's disease or senile dementia, and no associations were reported at any distance for Parkinson's disease, ALS, or multiple sclerosis.

The study's main limitation is the use of residential distance from transmission lines as a proxy for magnetic-field exposure (Maslanyj et al., 2009). It is also limited by the use of death certificate data, which are known to under-report Alzheimer's disease, and the lack of a full residential and occupational history. Furthermore, while the underlying cohort was very large, relatively few cases of Alzheimer's disease lived within 50 m of a high-voltage transmission line—20 cases total and 15 cases who lived at the residence for at least 15 years. This means that misclassification of a small number of cases could have a large impact on the risk estimate.

Another recent study used Sweden's large twin registry to assess whether occupational exposure to EMF was associated with dementia or Alzheimer's disease (Andel et al., 2010). Twins over the age of 65 were interviewed by phone to screen for possible dementia, and cases were identified for further evaluation to determine whether they had dementia or Alzheimer's disease (cases); study subjects without either diagnosis were considered the control group. Study subjects or their proxies were asked to identify their major lifetime occupation, which was linked with a job-exposure matrix to categorize EMF exposure into three, broad categories. In the overall twin population, EMF exposure was not associated with either dementia or Alzheimer's disease. An association with EMF was observed for those employed in manual labor and for those with early onset dementia ( $\leq 75$  years at diagnosis), but not Alzheimer's disease. This study's strength is the recruitment of living cases; however, small numbers limited the subgroup analyses and robust associations were not found.

In summary, two cohort studies of the Swiss population of relatively high quality were followed for death due to neurodegenerative disease. Röösli et al. (2007b) reported an association between Alzheimer's disease or senile dementia and occupational magnetic-field exposure, while Huss et al. (2009) reported an association between Alzheimer's disease or senile dementia and living within 50 m of a high-voltage transmission line for at least 15 years. Neither study reported an association with any other neurodegenerative disease, including ALS. A cohort of utility workers, however, did not confirm an association with Alzheimer's disease mortality and magnetic field exposure. The meta-analysis and supporting evaluation of study quality by García, Santibáñez, and colleagues confirmed that the associations reported in previous occupational studies are highly inconsistent and the studies have many limitations (Santibáñez et al., 2007; García et al., 2008).

The main limitations of these studies include the difficulty in diagnosing Alzheimer's disease; the difficulty of identifying a relevant exposure window given the long and nebulous course of this disease; the difficulty of estimating magnetic field exposure prior to the appearance of the disease; the under-reporting of Alzheimer's disease on death certificates; crude exposure evaluations that are often based on the recollection of occupational histories by friends and family given the cognitive impairment of the study participants; and the lack of consideration of both residential and occupational exposures or confounding variables.

The recent epidemiologic studies do not alter the conclusion that there is inadequate data on Alzheimer's disease or ALS. While a good number of studies have been published since the WHO review, little progress has been made on clarifying these associations. Further research is still required, particularly on electrical occupations and ALS (Kheifets et al., 2008). There is currently no body of *in vivo* research to suggest an effect and two studies reported no effect of magnetic fields on ALS progression (Seyhan and Canseven, 2006; Pouletier de Gannes et al., 2009). These conclusions are consistent with the recent review by the SCENIHR (SCENIHR, 2009).

**Table 8. Relevant studies of neurodegenerative disease published after the WHO review**

Authors	Year	Study
Andel et al.	2010	Work-related exposure to extremely low-frequency magnetic fields and dementia: Results from the population-based study of dementia in Swedish twins
Davanipour et al.	2007	A case-control study of occupational magnetic field exposure and Alzheimer's disease: results from the California Alzheimer's Disease Diagnosis and Treatment Centers
García, et al.	2008	Occupational exposure to extremely low frequency electric and magnetic fields and Alzheimer disease: a meta-analysis
Huss, et al.	2009	Residence near power lines and mortality from neurodegenerative diseases: longitudinal study of the Swiss population
Pouletier de Gannes et al.	2009	Amyotrophic lateral sclerosis (ALS) and extremely-low frequency (ELF) magnetic fields: a study in the SOD-1 transgenic mouse model
Röösli, et al.	2007b	Mortality from neurodegenerative disease and exposure to extremely low-frequency magnetic fields: 31 years of observations on Swiss railway employees
Santibáñez, et al.	2007	Occupational risk factors in Alzheimer's disease: a review assessing the quality of published epidemiological studies
Seidler et al.	2007	Occupational exposure to low frequency magnetic fields and dementia: a case-control study
Seyhan and Canseven	2006	In vivo effects of ELF MFs on collagen synthesis, free radical processes, natural antioxidant system, respiratory burst system, immune system activities, and electrolytes in the skin, plasma, spleen, lung, kidney, and brain tissues
Sorahan and Kheifets	2007	Mortality from Alzheimer's, motor neurone and Parkinson's disease in relation to magnetic field exposure: findings from the study of UK electricity generation and transmission workers, 1973-2004

### **3 Other Areas of Research**

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#### **Pacemakers and implanted cardiac devices**

The sensing system of pacemakers and other implanted cardiac devices (ICD) is designed to be responsive to the heart's electrical signal. For this reason, other electrical signals potentially can interfere with the normal functioning of pacemakers and ICDs, a phenomenon called electromagnetic interference (EMI). Most sources of EMF are too weak to affect a pacemaker or ICD; however, EMF from certain sources, e.g., some appliances and industrial equipment, may cause interference. This section considers potential EMI with implanted cardiac devices such as pacemakers and defibrillators.

In the presence of electromagnetic fields, pacemakers and ICDs can respond in different ways, defined as modes. The probability of interference occurring and the mode of the response depend on the strength of the interference signal, the patient's orientation in the electromagnetic field, the exact location of the device, and the variable parameters of the device that are specific to a patient.

There are a number of experimental studies dating back to the 1990s that were conducted to assess whether interference may occur when currents are induced in the patient's body by electric or magnetic fields (e.g., Toivonen et al., 1991; Astridge et al., 1993; Scholten and Silny, 2001). In general, pacing abnormalities in these tests occurred at magnetic field levels that are much higher than the levels a person would encounter on a daily basis. Electric fields did produce interference at levels that can be produced by certain electrical sources, but most pacemakers were not affected by high levels of electric fields (up to 20 kV/m) and did not exhibit any pacing abnormalities. Unipolar (single lead) pacemakers tended to be more sensitive to electric fields compared to bipolar (two lead) devices, which are designed specifically to reduce the effects of EMI.

A recent study by Joosten et al. (2009) confirmed earlier work by Scholten and Silny (2001). Both studies found that the performance of a pacemaker in the presence of external ELF electric fields varied considerably based on anatomical and physiological conditions. The 15 study

subjects in Joosten et al. experienced a variance of up to 200% when the interference voltage was applied at the input of their cardiac pacemakers. This variance was due to individual, personal factors such as state of respiration, systole and diastole of the heart, filling of the stomach, and muscle activity. The authors' analyses further suggested that for a 50-Hz electric field to affect the function of the most sensitive unipolar pacemaker, the field levels would have to be between 4.3 kV/m and 6.2 kV/m. Unipolar pacemakers are less and less common today; the study authors found that in Germany, only 6% of the pacemakers in use have a unipolar sensing system.

Suggested exposure levels have been determined by the American Conference of Governmental Industrial Hygienists (ACGIH) and the Electric Power Research Institute (EPRI) to prevent against pacemaker EMI. Both organizations suggest that exposures be kept below 1.5-2 kV/m for electric fields and the ACGIH recommends an exposure level not to exceed 1 G for magnetic fields (ACGIH 2001, EPRI 2004). These recommendations are general in nature and do not address that classes of pacemakers from some manufacturers are quite immune to interference even at levels much greater than these recommended guidelines. Both the ACGIH and EPRI recommend that patients consult their physicians and the respective pacemaker manufacturers before following these organizations' guidelines.

In addition, the Food and Drug Administration's Center for Devices and Radiological Health has issued guidelines for both the development of pacemakers and the design of new electrical devices to minimize susceptibility to electrical interference from any source. Pacemakers are designed to filter out electrical stimuli from sources other than the heart, e.g., the muscles of the chest, currents encountered from touching household appliances, or currents induced by external electric or magnetic fields. Used in both temporary and permanent pacemakers, these electrical filters increase the pacemaker's ability to distinguish extraneous signals from legitimate cardiac signals (Toivonen et al., 1991). Furthermore, most circuitry of modern pacemakers is encapsulated by titanium metal, which insulates the device by shielding the pacemaker's pulse generator from electric fields. Some pacemakers also may be programmed to pace the heart automatically if interference from electric or magnetic fields is detected (fixed pacing mode). This supports cardiac function and allows the subject to feel the pacing and move away from the source.

Due to recent design improvements, many pacemakers currently in use would not be susceptible to low intensity electric fields. There remains a very small possibility that some pacemakers, particularly those of older design and with single-lead electrodes, may sense potentials induced on the electrodes and leads of the pacemaker and provide unnecessary stimulation to the heart.

In summary, interference from strong electric fields is theoretically possible under certain circumstances. The likelihood of interference occurring is low, however, particularly with respect to sources that produce low levels of electric fields and when modern devices are implanted. It is recommended that concerned patients contact their doctors to discuss the make and model of their implanted device, their clinical condition, and any lifestyle factors that put them in close contact with strong electric or magnetic fields.

## Flora

Electric currents are involved in cell to cell communication in plants (Framm and Lautner, 2007). For this reason, numerous laboratory and on-site studies over the past 35 years have been conducted to assess the possible effects of exposure to ELF EMF from transmission lines on flora—including agricultural crops, trees, and forest and woodland vegetation (e.g., Hodges et al., 1975; Bankske et al., 1976; McKee et al., 1978; Miller et al., 1979; Rogers et al., 1980; Lee and Clark, 1981; Warren et al., 1981; Rogers et al., 1982; Greene 1983; Hilson et al., 1983; Hodges and Mitchell, 1984; Brulfert et al., 1985; Parsch and Norman, 1986; Conti et al., 1989; Krizaj and Valencic 1989; Ruzic et al., 1992; Reed et al., 1993; Smith et al., 1993; Mihai et al., 1994; Davies 1996; Zapotosky et al., 1996). Researchers have found no adverse effects on plant responses from exposure to EMF levels comparable to that produced by high-voltage transmission lines, including seed germination, seedling emergence and growth, leaf area per plant, flowering, seed production, longevity, and biomass production. The one confirmed adverse effect was damage to the tops of trees growing under or within 40 feet of an *experimental* transmission line operating at a voltage of 1,200 kV, attributable to corona-induced damage to branch tips. The right-of-way (ROW) clearance on *operational* transmission lines is typically a 100 to 200 foot clearance on each side of the line; this area would be cleared of trees or the branches trimmed back sufficiently to prevent flashover and other interference. This effect is not relevant to trees growing at greater distances from the ROW clearance area.

Experimental studies of plants have suggested that magnetic fields increased plant size and weight for radish and barley but not mustard plants (Davies, 1996). A group of studies evaluated the influence of ELF EMF on germination, seedling growth, and subsequent yield. Huang and Wang (2008) evaluated the effects of magnetic fields on the early seed germination of mung beans. The exposures from an inverter system were applied at six different frequencies between 10 Hz and 60 Hz, producing magnetic-field levels from 6 mG to 20 mG. The authors found that magnetic-field exposure at frequencies of 20 and 60 Hz enhanced early mung bean growth, while magnetic fields induced by 10, 30, 40, and 50 Hz frequencies had an inhibitory effect on early mung bean growth. Costanzo (2008) performed a similar study of soy beans exposed *in vitro* to 50-Hz electric fields at strengths of 1.3 kV/m and 2.5 kV/m (root mean square). The author found that this exposure increased soy bean growth in length. In addition, this same study reported that direct current (DC) electric fields of the same peak to peak value had no effect (Costanzo, 2008). A study of 60 Hz magnetic-field treatments of 80,000-200,000 mG on tomato seeds found exposure significantly improved seed performance *in vitro* and plant yield in the soil (De Souza et al., 2010).

Thus, researchers have found no adverse effects on plant responses at the levels of EMF produced by typical high- or low-voltage transmission lines.

## Fauna

Since the 1970s, research has been conducted on the possible effect of EMF on wild and domestic animals in response to concerns about the effects of high-voltage and ultra-high-voltage transmission lines in the vicinity of farms and the natural habitat of wild animals. National agencies and universities have conducted research on an assortment of fauna using a variety of study designs including observational studies of animals in their natural habitats and highly-controlled experimental studies. The research to date does not suggest that AC magnetic or electric fields (or any other aspect of high-voltage transmission lines, such as audible noise) result in adverse effects on the health, behavior, or productivity of fauna, including livestock (e.g., dairy cows, sheep, and pigs) and a variety of other species (e.g., small mammals, deer, elk, birds, and bees).

## Dairy Cattle and Deer

Burchard et al. (2007) is the most recent publication in a long-term series of controlled studies conducted at McGill University (e.g., Rodriguez et al., 2002, 2003, 2004; Burchard et al., 2003; 2004) on the possible effects of strong and continuous EMF exposure on the health, behavior, and productivity of dairy cattle. The broad goal of this research program was to assess whether EMF exposure could mimic the effect of days with long periods of light and increase milk production and feed intake through a hormonal pathway involving melatonin. In previous studies, some differences were reported between EMF-exposed and unexposed cows; however, they were not reported consistently between studies, the changes were still within the range of what is considered normal, and it did not appear that the changes were adverse in nature.

The study by Burchard et al. in 2007 differed from previous studies in that the exposure was restricted to magnetic fields; the outcomes evaluated included the hormones progesterone, melatonin, prolactin, and insulin-like growth factor 1 (IGF-1), as well as feed consumption. No significant differences in melatonin levels, progesterone levels, or feed intake were reported. Significant decreases in prolactin and IGF-1 levels were reported. Thus, similar to the previous studies by this group of investigators, Burchard et al. (2007) did not report findings that suggest magnetic fields cause changes in the melatonin pathway that could result in effects on reproduction or milk production.

The research does indicate that some species of animals are able to detect and orient to DC magnetic fields at levels associated with the earth's static geomagnetic field (~ 500 mG), and this detection may be important for navigational purposes (in particular for species such as birds). Based upon the characteristics of the major hypothesized detection mechanisms and testing in some species, it seems unlikely that a weak 60-Hz magnetic field would be detected or that it would perturb navigational functions.

Along these lines, two studies, both of which received considerable press attention, published analyses of the orientation of cattle and deer using satellite images and field observations that identify a possible geomagnetic component influencing the animals' behavior. A report by Begall et al. (2008) found that domestic cattle and red and roe deer tend to orient their bodies pointing in a northerly direction. The authors' hypothesize that this body orientation is related

to the earth's static geomagnetic field because in areas where the earth's magnetic North Pole can be distinguished more easily from the geographic North Pole's high magnetic declination, body orientation appeared to point more towards the magnetic north rather than the geographic north. This northerly body orientation was not correlated with time of day or the position of the sun, and although the authors speculated that the orientation of the animals was not influenced by wind, no analyses were presented. Based on these limited and indirect data the authors raised the possibility that these species can detect the earth's geomagnetic field.

In the second study, Burda et al. (2009) also explored the possible magnetic basis for the northerly orientation of cattle and deer by analyzing their behavior in the vicinity of high-voltage power lines. They report that cattle within 150 m and deer within 50 m of high-voltage power lines exhibit a random body orientation with respect to magnetic north. Some of the effect might be attributed to the deflection of the geomagnetic field by steel towers close to the line, but the authors did not test this possibility. Other analyses indicated that the orientation of cattle differed around power lines running in an east-west or north-south direction, which suggests that neither sun nor wind cues explain the orientation of these animals with respect to magnetic north. If the observed orientations of cattle and deer are attributable to the earth's geomagnetic field, the biological significance is not clear and the authors suggest additional experimental study. With respect to deer, the authors commented that deer prefer to locate near power lines, perhaps because of the browse or shelter afforded.

## **Wild Bees and Honey Bees**

Wild bees have an important role in natural plant and forest ecosystems. Research on wild bees was conducted at a site near a United States Navy communications system in Northern Michigan where two species of honeybees were observed living in the vicinity of this facility. The researchers studied the bees' exposure to 76-Hz electric and magnetic fields produced by the facility's communications system and compared the mortality, foraging behavior, and nest architecture to a group of honeybees living at a distance from the facility. A few differences were found in nesting parameters, although the effects were small, inconsistent, and likely due to other factors. Although a small increase in the overwinter mortality was reported in one of the two species studied, the researchers concluded that since the reported differences were small

and inconsistent between experiments, there were no findings that raised concern about ELF EMF exposures to wild bees (Zapotosky et al., 1996). This conclusion was confirmed in a review by the United States National Academy of Sciences (NAS, 1997).

More research has focused on commercial honeybees since farmers often place hives on fields near transmission lines. Greenberg et al. (1981) studied the effect of a 765-kV transmission line on honeybee colonies placed at varying distances from the transmission line's centerline, with some hives exposed to EMF from the line and some shielded. Differences between the shielded and unshielded hives were reported at exposures above 4.1 kV/m, including decreases in hive weight, abnormal amounts of propolis at hive entrances, increased mortality and irritability, loss of the queen in some hives, and a decrease in the hive's overwinter survival.

These adverse effects were reported only in the unshielded group. Since the shielding only prevented exposure to electric fields, not magnetic fields, the results indicate that these adverse effects are attributable to electric field exposure. These results have been replicated by other investigators (Rogers et al., 1980, 1981, 1982). Further studies indicated that the effects were indirect, i.e., the electric fields were not affecting the bees directly, and that field levels greater than 200 kV/m were required to affect the behavior of free-flying bees. Thus, heating of the hive by induced currents caused some of the adverse effects and the rest were attributed to shocks within the hive (Bindokas et al., 1988a, 1988b, 1989). Prevention is easily accomplished by placing a grounded metal cover on top of the hive.

Since the nests of wild bees in the ground or in trees contain no metal or highly conductive materials, there appears to be little relevance of such effects to wild bees. At these locations, wild bees also are naturally shielded from electric fields. Laboratory studies indicate that bees are unable to discriminate 60-Hz magnetic fields reliably at intensities less than 4,300 mG, although they can detect fluctuations in the earth's static geomagnetic field as weak as 0.26 mG (Kirschvink et al., 1997). The difference in the sensitivity of honey bees is an illustration that a sensory mechanism has developed to detect static magnetic fields that effectively rejects extraneous signals, in this case AC (60-Hz) magnetic fields.

## Birds

A recent study by Dell'omo et al. (2009) analyzed the effects of exposure to magnetic fields from high-voltage power lines during the embryonic and post-hatching period of kestrel nestling. The authors found that exposure does not have any significant short-term physiological effects on these birds.

The ability of birds to detect and use of the earth's geomagnetic field during migration does not translate to a capability to detect 60-Hz magnetic fields. Scientists have hypothesized that the mechanism for detection of the earth's geomagnetic field by birds (and bees), for which there is the most evidence, indicates they would be far less sensitive to 60-Hz magnetic fields. The WHO suggested that power frequency fields at intensities much less than the earth's geomagnetic field of around 500 mG are unlikely to be of much biological significance in relation to birds' navigational abilities because the changes produced by ELF magnetic fields and static magnetic fields are similar (WHO, 2007).

Finally, in a study by Elmusharaf et al. (2007), veterinarians in the Netherlands noted the beneficial effects of AC magnetic fields in poultry. The researchers infected broiler chickens with coccidiosis and reported that exposure to a 50 mG AC magnetic field for 30 minutes each day for a course of 15 days prior to infection provided significant protection against intestinal lesions and reduced growth characteristic of this disease.

Overall, the research over the course of the past 35 to 40 years does not suggest that electric or magnetic fields result in any adverse effects on the health, behavior, or productivity of fauna, including livestock, small mammals, deer, elk, birds, and bees.

## Marine Life

Although transmission lines mostly traverse the land they also frequently cross water bodies as well. Therefore, the potential for effects on certain marine ecological systems are evaluated regarding the potential impact of EMF on aquatic species in rivers and creeks. To date, there is little or no evidence that fish, mammals, or birds exhibit any harmful effects when exposed to EMF of frequencies close to or at power frequencies (50-60 Hz) at levels found under

transmission lines, even for a prolonged period of time (e.g., NRC, 1997a, 1997b; NIEHS 1998; WHO, 2007a). Thus, there is no concern that EMF would have any direct toxic effects on the marine biota.

A number of fish species, however, are reported to make use of the earth's geomagnetic field in navigation and migration, including Pacific salmon (*Oncorhynchus spp.*); the chinook salmon (*O. tshawytscha*) and the steelhead (*O. mykiss*) species particularly spend their adult lives in estuarine or oceanic environments and are well known for their annual spawning runs into freshwater, returning to the home streams and rivers where they were spawned and spent the first few months of their lives (Groot and Margolis, 1998). Pacific salmon are an important part of the history, ecology, and economy of the Pacific Northwest region.

Transmission lines will be a source of potential exposure to 60-Hz magnetic fields in rivers and streams below the conductors, but not electric field exposure because the water shields the fish from electric fields. Since the level of EMF decreases with distance from the source, maximum magnetic-field exposures of fish will occur when they are directly under the lines. The magnetic field levels in rivers and streams below transmission lines would be expected to be significantly lower than for spans on land because clearances for river and stream crossings are usually much higher. Additionally, prolonged exposure is not a critical issue as the fish species of most interest are migratory by nature and will only be exposed to magnetic fields during the relatively short time they take to spawn or travel down or up the river during their life cycle.

The Pacific salmon have been thought to navigate by several mechanisms: detecting and orienting to the earth's geomagnetic field, using a celestial compass (i.e., based on the position of the sun in the sky), and using their innate ability to imprint on their home stream by odor (Groot and Margolis, 1998, Quinn et al, 1981).

Generally, scientific studies have reported that, along with other cues or biological mechanisms, certain species of birds, bees, and fish may have magnetite in certain organs in their bodies, and use magnetite crystals as an aid in navigation (Bullock, 1977; Wiltschko and Wiltschko, 1991, Kirschvink et al, 1993, Walker et al. 1988). Crystals of magnetite have been found in Pacific salmon (Mann et al, 1998; Walker et al, 1998). These magnetite crystals are believed to serve as a compass that orients to the earth's magnetic field. Other studies, however, have not found

magnetite in sockeye salmon (*Oncorhynchus nerka*) fry (Quinn et al., 1981). While salmon can apparently detect the geomagnetic field, their behavior is governed by multiple stimuli as demonstrated by the ineffectiveness of magnetic field stimuli in the daytime (Quinn et al., 1982) and the inability of strong magnetic fields from permanent magnets attached to sockeye salmon (Ueda et al., 1998) or other salmon (Yano et al., 1997) to alter their migration behavior.

An important consideration is that the earth's geomagnetic field is static (0 Hz), in contrast to the oscillating magnetic field created by AC transmission lines, which produce current that changes direction and intensity 60 times per second. Static magnetic fields have fixed polarity, i.e. the earth's magnetic north and south poles. AC transmission lines produce magnetic fields that do not have fixed polarity.

No studies have been conducted to date that specifically examine the effects of AC magnetic fields on the salmon's ability to orient to the earth's geomagnetic field. Theoretical calculations do not suggest that 60-Hz magnetic fields could affect magnetite at levels less than 50 mG (Adair 1994). Studies on the response of other organisms that also use magnetite crystals as one means of navigation can, however, provide useful insight regarding salmon. Kirschvink et al. (1993) reports studies of the effects of AC magnetic fields on honey bees, which use magnetite crystals to navigate. In this study, the honey bees only oriented to an AC magnetic field when it was one million times greater in intensity than the DC field needed to elicit the same orientation response. This difference in intensity indicates that the AC magnetic field is less influential than the DC magnetic field in the navigation of honey bees and potentially other organisms that orient to the earth's geomagnetic field using magnetite crystals (Kirschvink et al., 1993). The level of AC magnetic fields under transmission lines are well below the levels reported in that study.

The scientific literature does not support the conclusion that the EMF associated with the proposed transmission line will have an adverse impact on the survival, growth, and reproduction of organisms in a marine ecosystem. There are no data on the effects of AC EMF on salmon navigation, but based on a study with honey bees, it appears that organisms that use magnetite crystals to orient to the earth's geomagnetic field would be affected only when the field levels are very much greater than the levels expected from a transmission line. Given this

evidence and the salmon's ability to navigate using multiple sensory cues, overhead transmission lines are unlikely to have an adverse impact on these species of interest and the aquatic ecosystems of these creeks.

## 4 Standards and Guidelines

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Scientific agencies develop exposure standards and guidelines to protect against known health effects following a thorough review of the relevant research. One of the main objectives of weight-of-evidence reviews is to identify the lowest exposure level below which no health hazards have been found (i.e., a threshold level). Exposure limits are then set *well below* the threshold level established by these reviews to take into account individual variability and sensitivity that may exist in susceptible populations.

The only effects known to be produced in humans by exposure to ELF EMF are seen at very high field levels to which the average person is not typically exposed. The effects are short-term, immediate, perceptible reactions to the electrical stimulation of the muscle and the nervous system. These effects are neither severe nor life-threatening.

Two international scientific organizations, ICNIRP and ICES, have published guidelines for limiting public exposure to ELF EMF to protect against these effects (ICNIRP, 1998, 2010; ICES, 2002). ICNIRP is an independent organization of scientists from various disciplines with expertise in the field of non-ionizing radiation assembled from around the world. It is the formally recognized, non-governmental organization that develops safety guidance for non-ionizing radiation for the WHO, the International Labour Organization, and the European Union.

The ICES is sponsored by the American National Standards Institute and IEEE. The mandate for ICES is the “Development of standards for the safe use of electromagnetic energy in the range of 0 Hz to 300 GHz relative to the hazards of exposure to man ... to such energy.”<sup>25</sup> The ICES encourages a balanced international volunteer participation from several sectors: the interested general public; the scientific, health and engineering communities; agencies of governments; energy producers; and energy users.

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<sup>25</sup> The ICES is a 50-year-old internationally recognized, EMF standard-setting organization, which is sponsored by the IEEE that itself was established in 1884. The ICES should not be confused with a group of scientists who have acted together as an advocacy group and banded together under the similar name of the International Commission for Electromagnetic Safety in 2003.

Although both organizations have the same objectives and use similar methods, their recommended exposure limits to 60-Hz EMF for the general public differ (Table 9). The ICNIRP recommends screening values for magnetic fields of 2,000 mG for the general public and 10,000 mG for workers (ICNIRP, 2010). The ICES recommends maximum permissible exposure of 9,040 mG for magnetic fields (ICES, 2002). The ICNIRP's screening value for exposure to 60-Hz electric fields for the general public is 4.2 kV/m and the ICES screening value is 5 kV/m. Both organizations allow higher exposures if it can be demonstrated that exposures do not produce current densities or electric fields within tissues that exceed basic restrictions on internal current densities or electric fields.

**Table 9. Reference levels for whole body exposure to 60-Hz fields: general public**

<b>Organization recommending limit</b>	<b>Magnetic fields</b>	<b>Electric fields</b>
ICNIRP restriction level	2,000 mG	4.2 kV/m
ICES maximum permissible exposure (MPE)	9,040 mG	5 kV/m 10 kV/m <sup>a</sup>

<sup>a</sup> This is an exception within transmission line ROWs because people do not spend a substantial amount of time in ROWs and very specific conditions are needed before a response is likely to occur (i.e., a person must be well insulated from ground and must contact a grounded conductor) (ICES, 2002, p. 27).

These guidelines were developed following a weight-of-evidence review of the literature by each organization, including epidemiologic and experimental evidence related to both short-term and long-term exposure. Both reviews concluded that the stimulation of nerves and the central nervous system could occur at very high exposure levels immediately upon exposure. While ICNIRP and ICES reference levels for electric fields are similar, the reference levels for magnetic fields differ by a factor of 10. As explained by Reilly (2005), this difference results from the way the two guidelines have extrapolated responses of the retina of the eye to magnetic fields at around 20 Hz to higher frequencies and other tissues. Their reviews also concluded that there was not sufficient evidence to support a causal role for EMF in the development of cancer or other long-term adverse health effects. Therefore, neither organization found a basis to recommend quantitative exposure guidelines to prevent effects at lower exposure levels.

Following the publication of their 1998 guidelines, the ICNIRP published an evaluation of the epidemiologic literature (ICNIRP, 2001) and a full weight-of-evidence evaluation of health

research on EMF (ICNIRP, 2003), concluding again that there is no basis for exposure restrictions for long-term health effects. In June 2009, the ICNIRP published an updated review of the scientific literature related to potential short- and long-term adverse effects, and *draft* guidelines to replace their 1998 ELF EMF exposure guidelines (ICNIRP, 2009). The final guideline was published in December 2010 and those screening values are listed in Table 9.

There are no national or state standards in the United States limiting exposures to ELF EMF based on health effects. Two states, Florida and New York, have enacted standards to limit magnetic fields at the edge of transmission line ROWs (150 mG and 200 mG, respectively) (NYPSC, 1978, 1990; FDER, 1989; FDEP, 1996). The basis for limiting magnetic fields from transmission lines was to maintain the status quo so that fields from new transmission lines would be no higher than those produced by existing transmission lines.

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## **Appendix 1**

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### **World Health Organization International EMF Project Summary of Conclusions**

## Overview

The World Health Organization (WHO) is a scientific organization within the United Nations system whose mandate includes providing leadership on global health matters, shaping the health research agenda, and setting norms and standards. WHO established the International EMF Project in 1996, in response to public concerns about exposures to electric and magnetic fields (EMF) and possible adverse health effects. The Project's membership includes 8 international organizations, 8 collaborating institutions, and over 54 national authorities. The overall purpose of the project is to assess health and environmental effects of exposure to static and time-varying EMF in the frequency range 0-300 gigahertz (GHz). A key objective is to evaluate the scientific literature and make a status report on health effects, to be used as the basis for a coherent international response, including the identification of important research gaps and the development of internationally acceptable standards for EMF exposure. This status report was published in June 2007 as part of WHO's Environmental Health Criteria (EHC) Programme.

The Monograph used standard scientific procedures, as outlined in the Preamble, to conduct its weight-of-evidence review.<sup>1</sup> The Task Group responsible for the report's overall conclusions consisted of 21 scientists from around the world with expertise in a wide range of disciplines. The Task Group relied on the conclusions of previous weight-of-evidence reviews, where possible, and (with regard to cancer) mainly focused on evaluating studies published after the IARC review in 2002. Specific terms were used by the Task Group to describe the strength of the evidence in support of causality. *Limited evidence* describes a body of research where the findings are inconsistent or there are outstanding questions about study design or other methodological issues that preclude making strong conclusions. *Inadequate evidence* describes a body of research where it is unclear whether the data is supportive or unsupportive of causation because there is a lack of data or there are major quantitative or qualitative issues.

The following sections describe the conclusions of the WHO by health outcome (cancer, reproductive effects, and neurodegenerative diseases). The conclusions and perspectives of

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<sup>1</sup> The term "weight-of-evidence review" is used in this report to denote a systematic review process by a multidisciplinary, scientific panel involving experimental and epidemiologic research to arrive at conclusions about possible health risks. The WHO Monograph on EMF does not specifically describe their report as a weight-of-evidence review. Rather, they describe conducting a health risk assessment. Although the two terms are similar, a health risk assessment differs from a weight-of-evidence review in that it also incorporates an exposure assessment and an exposure-response assessment.

weight-of-evidence reviews conducted by other scientific organizations are discussed, where appropriate, to highlight consistencies and inconsistencies in conclusions.

## Conclusions

### Cancer

The overwhelming majority of health research related to EMF has focused on the possibility of a relationship with cancer, including leukemia, lymphoma, breast cancer, and brain cancer. The vast majority of epidemiologic studies in this field enrolled persons with a specific cancer type (*cases*); selected a group of individuals similar to the cancer cases (*controls*); estimated past magnetic or electric field exposures, or both; and compared these exposures between the cases and controls to test for statistical differences. Some of these studies looked for statistical associations of these diseases with magnetic fields produced by nearby power lines (estimated through calculations or distance) or appliances, while other studies actually measured magnetic field levels in homes or estimated personal magnetic field exposures from all sources. In studies of adult cancers, occupational magnetic field exposures were estimated in some studies, as well. *In vivo* studies in this field exposed animals to high levels of magnetic fields (up to 50,000 milligauss [mG]) over the course of their entire lifetime to observe whether exposed animals had higher rates of cancer than unexposed animals. Some of these studies exposed animals to magnetic fields in tandem with a known carcinogen to test whether magnetic field exposure promoted carcinogenesis. Since there is relatively low energy associated with extremely low-frequency (ELF) EMF, researchers believe it is highly unlikely that electric or magnetic fields can directly damage DNA. Therefore, *in vitro* studies in this field have largely focused on investigating whether ELF EMF could promote damage from other known carcinogens or cause cancer through a pathway other than DNA damage (e.g., hormonal or immune effects or alterations in signal transduction).

The International Agency for Research on Cancer (IARC) is the division of the WHO with responsibility to coordinate and conduct research on the causes of human cancer and the mechanisms of carcinogenesis and to develop scientific strategies for cancer control. The IARC convened a scientific panel in 2001 to conduct an extensive review and arrive at a conclusion about the possible carcinogenicity of EMF (IARC, 2002). The IARC has a standard method for classifying exposures based on the strength of the scientific research in support of carcinogenicity.

Categories include (from highest to lowest risk): carcinogenic to humans, probably carcinogenic to humans, possibly carcinogenic to humans, unclassifiable, and probably not carcinogenic to humans. As a result of two pooled analyses reporting an association between high, average magnetic field exposure and childhood leukemia, the epidemiology data was classified as providing “limited evidence of carcinogenicity”<sup>2</sup> in relation to childhood leukemia. With regard to all other cancer types, the epidemiology evidence was classified as inadequate. The IARC panel also reported that there was “inadequate evidence of carcinogenicity” in studies of experimental animals. Overall, magnetic fields were evaluated as “possibly carcinogenic to humans.” The IARC usage of “possible” denotes an exposure in which epidemiologic evidence points to a statistical association, but other explanations cannot be ruled out as the cause of that statistical association (e.g., bias and confounding)<sup>3</sup> and experimental evidence does not support a cause-and-effect relationship. Considering recently published epidemiology, *in vivo*, and *in vitro* research, the WHO concluded that the classification of “possible carcinogen” remains accurate (WHO, 2007).

## **Childhood Leukemia**

The issue that has received the most attention is childhood leukemia. Research in this area was prompted by an epidemiology study of children in the United States that reported a statistical association between childhood leukemia and a higher predicted magnetic field level in the home based on characteristics of nearby distribution and transmission lines (Wertheimer and Leeper, 1979). Subsequently, some epidemiologic studies reported that children with leukemia were more likely to live closer to power lines or have higher estimates of magnetic field exposure (compared to children without leukemia), while other epidemiologic studies did not report this statistical association. Of note, the largest epidemiology studies of childhood leukemia that actually measured personal magnetic field exposure (as opposed to estimating exposure through

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<sup>2</sup> Each type of evidence is categorized based on the strength of the evidence in support of carcinogenicity. The categories include: sufficient evidence of carcinogenicity, limited evidence of carcinogenicity, inadequate evidence of carcinogenicity, and evidence suggesting lack of carcinogenicity. If a positive association between an exposure and cancer is found (although factors such as chance, bias and confounding cannot be ruled out with reasonable confidence), the epidemiologic evidence is rated as “limited evidence of carcinogenicity.” If chance, bias and confounding can be ruled out with reasonable confidence, then the evidence is classified as “sufficient evidence of carcinogenicity.” The *in vivo* studies are ranked using a similar system, and the totality of the evidence is then considered to reach a conclusion about a particular exposure’s carcinogenicity.

<sup>3</sup> Bias refers to any systematic error in the design, implementation or analysis of a study that results in a mistaken estimate of an exposure’s effect on the risk of disease. A confounder is something that is related to both the disease under study and the exposure of interest such that we cannot be sure what causes the observed association - the confounder or the exposure of interest.

calculations or distance) did not report evidence to support a causal relationship, nor did they report a dose-response relationship with exposure to higher magnetic field levels (Linet et al., 1997; McBride et al., 1999; UKCCS, 1999).

In 2000, researchers combined the data from previously published epidemiology studies of magnetic fields and childhood leukemia that met specified criteria (Ahlbom et al., 2000; Greenland et al., 2000). The researchers pooled the data on the individuals from each of the studies, creating a study with a much larger number of subjects and, as a result, greater statistical power to detect an effect (should one exist) than any single study. In both pooled analyses, a weak association was reported between childhood leukemia and estimates of average magnetic field exposures greater than 3-4 mG. The authors were appropriately cautious in the interpretation of their analyses, and noted the uncertainty related to pooling estimates of exposure obtained by different methods from studies of diverse design, as did other researchers (e.g., Elwood, 2006). Because of the inherent uncertainty associated with observational epidemiologic studies, the results of these pooled analyses were not considered to provide strong epidemiologic support for a causal relationship. Furthermore, *in vivo* studies have not found that magnetic fields induce or promote cancer in animals exposed under highly controlled conditions for their entire lifespan, nor have *in vitro* studies found a cellular mechanism by which magnetic fields could induce carcinogenesis. As discussed above, these findings resulted in the classification of magnetic fields as a possible carcinogen (IARC, 2002).

The WHO evaluated two more recently published studies related to childhood leukemia and magnetic fields (Draper et al., 2005; Kabuto et al., 2006). Draper et al. conducted a case-control study of childhood cancer, which included 9,700 children with leukemia (i.e., cases) and an equal number of children that did not have leukemia (i.e., controls). The study compared the distance of birth address to high-voltage transmission lines among cases and controls and reported a weak association between childhood leukemia and birth addresses within 600 feet of high-voltage transmission lines. Kabuto et al. conducted a smaller case-control study in Japan that measured the average weekly magnetic field in the bedrooms of 312 children with leukemia and 603 children without leukemia. The investigators reported that children with leukemia were more likely to have average magnetic field levels >4 mG compared to children without leukemia.

The WHO did not assign a high weight or significance to these studies in their overall evaluation, stating that the low participation rate in Kabuto et al. and the use of distance as a proxy for magnetic field exposure in Draper et al. were important limitations. Less weight should be placed on these studies relative to studies that used good exposure assessment techniques and had high participation rates. The WHO described the results of these two studies as consistent with the classification of limited epidemiologic evidence in support of carcinogenicity and, together with the largely negative *in vivo* and *in vitro* research, consistent with the classification of magnetic fields as a possible carcinogen.

The WHO concluded that several factors might be fully, or partially, responsible for the consistent association observed between high, average magnetic fields and childhood leukemia, including misclassification of magnetic field exposure due to poor exposure assessment methods, confounding from unknown risk factors, and selection bias.<sup>4</sup> The WHO concluded that reconciling the epidemiologic data on childhood leukemia and the negative (i.e., no hazard) experimental findings through innovative research is currently the highest priority in the field of ELF EMF research. Given that few children are expected to have average magnetic field exposures greater than 3-4 mG, however, the WHO stated that the public health impact of magnetic fields on childhood leukemia would be low if the association were causal.

## Breast Cancer

Research on breast cancer has examined the possible effects of ELF EMF from three sources: workplace exposures, residential exposure from power lines, and electric blankets. Some of the early epidemiology studies in this field reported a weak association between breast cancer and higher magnetic field exposures, while others did not; however, the conclusions that could be drawn from this initial body of research were limited because of study quality issues (e.g., poor exposure assessment, inadequate control for confounding variables, and small sample sizes within subgroups with reported associations). Review panels evaluating this initial body of research

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<sup>4</sup> Selection bias arises if there are differences in the persons who participate in a study compared to the persons who do not participate in a study that are related to the exposure and differential by case/control status. For example, if the parents of a child with leukemia were informed that the study was investigating magnetic field exposure and they resided close to a transmission line, they may be more likely to participate than a family that lived far from a transmission line. As a result, children with leukemia that lived closer to transmission lines (and with a presumably higher magnetic field exposure) would be over-represented in the study population compared to the source population. In this scenario, the study may report that children with leukemia are more likely to have higher magnetic field exposure when, if the entire source population of leukemia cases were to be considered, there would be no difference in the exposure levels between leukemia cases and controls.

concluded that the evidence in support of an association was weak, but should be further evaluated with higher quality studies (NRPB, 2001; IARC, 2002; ICNIRP, 2003).

A large number of studies on breast cancer and magnetic field exposure have been conducted since the publication of the IARC review in 2002. These studies were systematically reviewed by the WHO and included seven studies that estimated residential magnetic field exposure, four studies reporting associations with electric blanket usage, and nine studies that estimated occupational magnetic field exposure. No consistent associations between magnetic field exposure and breast cancer were reported in these studies. The WHO concluded that this recent body of research was higher in quality compared with previous studies, and, for that reason, provides strong support to previous consensus statements that magnetic field exposure does not influence the risk of breast cancer. In summary, the WHO stated “With these [recent] studies, the evidence for an association between ELF magnetic field exposure and the risk of female breast cancer is weakened considerably and does not support an association of this kind” (p. 9). The WHO recommended no further research with respect to breast cancer and magnetic field exposure.

Breast cancer has received additional attention because of some initial epidemiologic and experimental findings suggesting that magnetic fields may depress levels of the hormone melatonin (which is believed to have anti-carcinogenic effects), leading to the development of breast cancer. A comprehensive weight-of-evidence review by the Health Protection Agency of Great Britain (HPA) in 2006 concluded that the evidence to date did not support the hypothesis that exposure to magnetic fields affects melatonin levels, or the risk of breast cancer in general (HPA, 2006). The WHO also considered this body of research, concluding “Overall, these data do not indicate that ELF electric and/or magnetic fields affect the neuroendocrine system in a way that would have an adverse impact on human health and the evidence is thus considered inadequate” (p. 186).

## **Adult leukemia and brain cancer**

A large number of studies of variable quality and using a wide range of techniques have been conducted in both occupational and residential settings to explore the possible relationship between EMF exposure and adult brain cancer and leukemia. The scientific committees assembled by the IARC, NRPB, and ICNIRP concluded that the evidence is weak and does not support a role for electric or magnetic fields in the etiology of brain cancer or leukemia among adults (NRPB, 2001a; IARC, 2002; ICNIRP, 2003). The WHO reviewed the body of research published since the time of these reviews, including three studies estimating residential exposure, four cohort studies estimating occupational exposures, and eight case-control studies reported on occupation and brain cancer or leukemia risk. The WHO concluded, “In the case of adult brain cancer and leukaemia, the new studies published after the IARC monograph do not change the conclusion that the overall evidence for an association between ELF [EMF] and the risk of these disease remains inadequate” (p. 307). The WHO panel recommended updating the existing European cohorts of occupationally exposed individuals and then pooling the epidemiologic data on brain cancer and adult leukemia to confirm the absence of an association.

## ***In vivo and in vitro research on carcinogenesis***

It is standard procedure to conduct studies of laboratory animals to determine whether exposure to a specific agent leads to the development of cancer (USEPA, 2005). This approach is used because all known human carcinogens cause cancer in laboratory animals. In the field of ELF EMF research, a number of research laboratories have exposed rodents with a particular genetic susceptibility to cancer to high levels of magnetic fields over the course of their lifetime and performed tissue evaluations to assess the incidence of cancer in many organs. In these studies, magnetic field exposure has been administered alone (to test for the ability of magnetic fields to act as a complete carcinogen), in combination with a known carcinogen (to test for a promotional or co-carcinogenic effect), or in combination with a known carcinogen and a known promoter (to test for a co-promotional effect). The WHO described four large-scale, long-term studies of rodents exposed to magnetic fields over the course of their lifetime that did not report increases in any type of cancer (Mandeville et al., 1997; Yasui et al., 1997; Boorman et al., 1999a, 1999b; McCormick et al., 1999). No directly relevant animal model for childhood acute lymphoblastic leukemia (ALL) currently exists. Some animals, however, develop a type of lymphoma similar to

childhood ALL and studies exposing transgenic mice predisposed to this lymphoma to power-frequency magnetic fields have not reported an increased incidence of lymphoma associated with exposure (Harris et al., 1998; McCormick et al., 1998; Sommer and Lerchel 2004). Based on this body of research, the WHO panel concluded that exposure to ELF magnetic fields, does not appear to cause cancer alone, although it is a high priority to identify and perform studies on an animal model that is more directly relevant to childhood ALL.

Studies investigating whether exposure to magnetic fields can promote cancer or act as a co-carcinogen used known cancer-causing agents, such as ionizing radiation, ultraviolet radiation, or other chemicals. No effects were observed for studies on chemically-induced preneoplastic liver lesions, leukemia/lymphoma, skin tumors, or brain tumors; however, the incidence of DMBA-induced mammary tumors was increased with magnetic field exposure in a series of experiments (Löscher et al., 1993, 1994, 1997; Baum et al., 1995; Löscher and Mevissen, 1995; Mevissen et al., 1993a, 1993b, 1996a, 1996b, 1998), suggesting that magnetic field exposure increased the proliferation of mammary tumor cells. These results were not replicated in subsequent series of experiments in another laboratory (Anderson et al., 1999; Boorman et al. 1999; NTP, 1999), possibly due to differences in experimental protocol and the species strain (Fedrowitz et al., 2004). Some studies have reported an increase in genotoxic effects among exposed animals (e.g., DNA strand breaks in the brains of mice [Lai and Singh, 2004]), although the results have not been replicated.

In summary, the WHO concluded with respect to *in vivo* research, “There is no evidence that ELF exposure alone causes tumours. The evidence that ELF field exposure can enhance tumour development in combination with carcinogens is inadequate.” Recommendations for future research include the development of a rodent model for childhood ALL and the continued investigation of whether magnetic fields can act as a co-carcinogen.

*In vitro* studies are widely used to investigate the mechanisms for effects that are observed in humans and animals. The relative value of *in vitro* tests to human health risk assessment, however, is much less than that of *in vivo* and epidemiology studies. Responses of cells and tissues outside the body may not always reflect the response of those same cells if maintained in a living system, so the relevance of *in vitro* studies cannot be assumed (IARC, 1992).

The IARC and other scientific review panels that systematically evaluated *in vitro* studies concluded that there is no clear evidence indicating how ELF magnetic fields could adversely affect biological processes in cells (IARC, 2002; ICNIRP, 2003; NRPB, 2004). The WHO panel reviewed the *in vitro* research published since the time of these reviews and reached the same conclusion. The WHO noted that previous studies have not indicated a genotoxic effect of ELF magnetic fields on mammalian cells, however a recent series of experiments reported DNA damage in human fibroblasts exposed intermittently to 50-Hz magnetic fields (Ivancsits et al., 2002a, 2002b; Ivancsits et al., 2003a, 2003b). These findings have not been replicated by other laboratories (Scarfì et al., 2005), and the WHO recommended continued research in this area. Research in the field of *in vitro* genotoxicity of magnetic fields combined with known DNA-damaging agents is also recommended, following suggestive findings from several laboratories. As noted by the Swedish Radiation Protection Authority, the levels at which these effects were observed are much higher than the levels we are exposed to in our everyday environments and therefore are not directly relevant to questions about low-level, chronic exposures (SSI, 2007). *In vitro* studies investigating other possible mechanisms, including gene activation, cell proliferation, apoptosis, calcium signaling, intercellular communication, heat shock protein expression and malignant transformation, have produced “inconsistent and inconclusive” results (p. 347, WHO, 2007).

## **Reproductive Effects**

Epidemiology studies have been conducted to observe whether maternal or paternal EMF exposures are associated with adverse reproductive effects, including effects on fertility, reproduction, miscarriage, and prenatal and postnatal growth and development. A body of *in vivo* literature is also available on this topic. Early studies on the potential effect of EMF exposures on reproductive outcomes were limited because the majority of the studies used surrogate measures of exposure (including visual display terminal use, electric blanket use, or wire code data) or assessed exposure retrospectively.

Two recent studies related to miscarriage improved exposure assessment by directly measuring magnetic field exposure. These two studies reported a positive association between miscarriage and exposure to high maximum, or instantaneous, peak magnetic fields (Li et al., 2002; Lee et al., 2002). No consistent associations were reported, however, with high, average magnetic field

levels, the typical method for assessing magnetic field exposure. The WHO noted several issues that have been raised by other investigators and scientific review panels concerning the validity of these associations (HCN, 2004; NRPB, 2004; Feychting et al., 2005; Mezei et al., 2005; Savitz et al., 2006). First, the studies had a low response rate, which means that the case and control groups may not be comparable because those who participated in the study may have differed from those who declined (i.e., selection bias). Second, in the study by Lee et al. (2002), magnetic field measurements were taken 30 weeks after a woman's last menstrual period. Some of these women had already miscarried at 30 weeks when magnetic field exposure was measured. This introduces the possibility for bias because pregnancy may alter physical activity levels and physical activity may be associated with magnetic field exposure in pregnant women, as recently confirmed in a study by Savitz et al. (2006). It is possible that the women who miscarried prior to 30 weeks in the study by Lee et al. (2002) subsequently increased their physical activity levels (i.e., returned to work or their normal routine), which resulted in greater opportunities to encounter higher peak magnetic field levels. Furthermore, there is no biological basis to indicate that EMF increases the risk of reproductive effects. *In vivo* studies exposed animals to high levels of electric and magnetic fields and reported no significant, adverse developmental effects. The WHO stated that *in vivo* studies on other reproductive outcomes are inadequate at this time.

The WHO concluded that, overall, the body of research does not suggest that maternal or paternal exposures to ELF EMF cause adverse reproductive outcomes. The evidence from epidemiology studies on miscarriage is inadequate, and further research on this possible association is recommended, although low priority was given to this recommendation.

## **Neurodegenerative Diseases**

Research into the possible effect of magnetic fields on the development of neurodegenerative diseases began in 1995, and the majority of research since then has focused on Alzheimer's disease and a specific type of motor neuron disease called amyotrophic lateral sclerosis (ALS) or Lou Gehrig's disease. The inconsistency of the Alzheimer's studies prompted the National Radiological Protection Board of Great Britain (NRPB)<sup>5</sup> to conclude that there is "only weak evidence to suggest that it [i.e., extremely low frequency magnetic fields] could cause Alzheimer's

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<sup>5</sup> The NRPB merged with the Health Protection Agency in April 2005 to form its new Radiation Protection Division.

disease” (p. 20, NRPB, 2001b). Early studies on ALS, which had no obvious biases and were well conducted, reported an association between ALS mortality and estimated occupational magnetic field exposure. The review panels, however, were hesitant to conclude that the associations provided strong support for a causal relationship between ALS and occupational magnetic field exposure. The scientific panels felt that an alternative explanation (i.e., electric shocks received at work) may be the source of the observed association. The NRPB concluded: “In summary, the epidemiological evidence suggests that employment in electrical occupations may increase the risk of ALS, possibly, however, as a result of the increased risk of receiving an electric shock rather than from the increased exposure to electromagnetic fields” (p.20, NRPB, 2001b).

Most recent studies reported associations between occupational magnetic field exposure and mortality from Alzheimer’s disease and ALS, although the design and methods of these studies were relatively weak (disease status based on death certificate data, exposure based on incomplete occupational information from census data, and no control for confounding factors). There is currently no biological data to support an association between magnetic fields and neurodegenerative diseases. The WHO concluded that there is inadequate data in support of an association between magnetic fields and Alzheimer’s disease or ALS. The panel highly recommended that further studies be conducted in this area, particularly studies where the association between magnetic fields and ALS is estimated while controlling for the possible confounding effect of electric shocks.

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## **Appendix 2**

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### **WHO Fact Sheet**

Fact sheet N°322  
June 2007

## **Electromagnetic fields and public health**

### **Exposure to extremely low frequency fields**

The use of electricity has become an integral part of everyday life. Whenever electricity flows, both electric and magnetic fields exist close to the lines that carry electricity, and close to appliances. Since the late 1970s, questions have been raised whether exposure to these extremely low frequency (ELF) electric and magnetic fields (EMF) produces adverse health consequences. Since then, much research has been done, successfully resolving important issues and narrowing the focus of future research.

In 1996, the World Health Organization (WHO) established the International Electromagnetic Fields Project to investigate potential health risks associated with technologies emitting EMF. A WHO Task Group recently concluded a review of the health implications of ELF fields (WHO, 2007).

This Fact Sheet is based on the findings of that Task Group and updates recent reviews on the health effects of ELF EMF published in 2002 by the International Agency for Research on Cancer (IARC), established under the auspices of WHO, and by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) in 2003.

### **ELF field sources and residential exposures**

Electric and magnetic fields exist wherever electric current flows - in power lines and cables, residential wiring and electrical appliances. **Electric** fields arise from electric charges, are measured in volts per metre (V/m) and are shielded by common materials, such as wood and metal. **Magnetic** fields arise from the motion of electric charges (i.e. a current), are expressed in tesla (T), or more commonly in millitesla (mT) or microtesla ( $\mu$ T). In some countries another unit called the gauss, (G), is commonly used ( $10,000\text{ G} = 1\text{ T}$ ). These fields are not shielded by most common materials, and pass easily through them. Both types of fields are strongest close to the source and diminish with distance.

Most electric power operates at a frequency of 50 or 60 cycles per second, or hertz (Hz). Close to certain appliances, the magnetic field values can be of the order of a few hundred microtesla. Underneath power lines, magnetic fields can be about 20  $\mu$ T and electric fields can be several thousand volts per metre. However, average residential power-frequency magnetic fields in homes are much lower - about 0.07  $\mu$ T in Europe and 0.11  $\mu$ T in North America. Mean values of the electric field in the home are up to several tens of volts per metre.

### **Task group evaluation**

In October 2005, WHO convened a Task Group of scientific experts to assess any risks to health that might exist from exposure to ELF electric and magnetic fields in the frequency range  $>0$  to 100,000 Hz (100 kHz). While IARC examined the evidence regarding cancer in 2002, this Task Group reviewed evidence for a number of health effects, and updated the evidence regarding cancer. The conclusions and recommendations of the Task Group are presented in a WHO Environmental Health Criteria (EHC) monograph (WHO, 2007).

Following a standard health risk assessment process, the Task Group concluded that there are no substantive health issues related to ELF electric fields at levels generally encountered by members of the public. Thus the remainder of this fact sheet addresses predominantly the effects of exposure to ELF magnetic fields.

## Short-term effects

There are established biological effects from acute exposure at high levels (well above 100 µT) that are explained by recognized biophysical mechanisms. External ELF magnetic fields induce electric fields and currents in the body which, at very high field strengths, cause nerve and muscle stimulation and changes in nerve cell excitability in the central nervous system.

## Potential long-term effects

Much of the scientific research examining long-term risks from ELF magnetic field exposure has focused on childhood leukaemia. In 2002, IARC published a monograph classifying ELF magnetic fields as "possibly carcinogenic to humans". This classification is used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals (other examples include coffee and welding fumes). This classification was based on pooled analyses of epidemiological studies demonstrating a consistent pattern of a two-fold increase in childhood leukaemia associated with average exposure to residential power-frequency magnetic field above 0.3 to 0.4 µT. The Task Group concluded that additional studies since then do not alter the status of this classification.

However, the epidemiological evidence is weakened by methodological problems, such as potential selection bias. In addition, there are no accepted biophysical mechanisms that would suggest that low-level exposures are involved in cancer development. Thus, if there were any effects from exposures to these low-level fields, it would have to be through a biological mechanism that is as yet unknown. Additionally, animal studies have been largely negative. Thus, on balance, the evidence related to childhood leukaemia is not strong enough to be considered causal.

Childhood leukaemia is a comparatively rare disease with a total annual number of new cases estimated to be 49,000 worldwide in 2000. Average magnetic field exposures above 0.3 µT in homes are rare: it is estimated that only between 1% and 4% of children live in such conditions. If the association between magnetic fields and childhood leukaemia is causal, the number of cases worldwide that might be attributable to magnetic field exposure is estimated to range from 100 to 2400 cases per year, based on values for the year 2000, representing 0.2 to 4.95% of the total incidence for that year. Thus, if ELF magnetic fields actually do increase the risk of the disease, when considered in a global context, the impact on public health of ELF EMF exposure would be limited.

A number of other adverse health effects have been studied for possible association with ELF magnetic field exposure. These include other childhood cancers, cancers in adults, depression, suicide, cardiovascular disorders, reproductive dysfunction, developmental disorders, immunological modifications, neurobehavioural effects and neurodegenerative disease. The WHO Task Group concluded that scientific evidence supporting an association between ELF magnetic field exposure and all of these health effects is much weaker than for childhood leukaemia. In some instances (i.e. for cardiovascular disease or breast cancer) the evidence suggests that these fields do not cause them.

## International exposure guidelines

Health effects related to short-term, high-level exposure have been established and form the basis of two international exposure limit guidelines (ICNIRP, 1998; IEEE, 2002). At present, these bodies consider the scientific evidence related to possible health effects from long-term, low-level exposure to ELF fields insufficient to justify lowering these quantitative exposure limits.

## WHO's guidance

For high-level short-term exposures to EMF, adverse health effects have been scientifically established (ICNIRP, 2003). International exposure guidelines designed to protect workers and the public from these effects should be adopted by policy makers. EMF protection programs should include exposure measurements from sources where exposures might be expected to exceed limit values.

Regarding long-term effects, given the weakness of the evidence for a link between exposure to ELF magnetic fields and childhood leukaemia, the benefits of exposure reduction on health are unclear. In view of this situation, the following recommendations are given:

- Government and industry should monitor science and promote research programmes to further reduce the uncertainty of the scientific evidence on the health effects of ELF field exposure. Through the ELF risk assessment process, gaps in knowledge have been identified and these form the basis of a new research agenda.
- Member States are encouraged to establish effective and open communication programmes with all stakeholders to enable informed decision-making. These may include improving coordination and consultation among industry, local government, and citizens in the planning process for ELF EMF-emitting facilities.
- When constructing new facilities and designing new equipment, including appliances, low-cost ways of reducing exposures may be explored. Appropriate exposure reduction measures will vary from one country to another. However, policies based on the adoption of arbitrary low exposure limits are not warranted.

## Further reading

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## **Appendix 3**

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### **Comment on the BioInitiative Report**

## Background

In August 2007, an *ad hoc* group of 14 scientists and public health and policy consultants published an on-line report titled “*The BioInitiative Report: A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF)*.” The group’s objective was to “assess scientific evidence on health impacts from electromagnetic radiation below current public exposure limits and evaluate what changes in these limits are warranted now to reduce possible public health risks in the future” (p. 4). The individuals who comprised this group did not represent any well-established regulatory agency, nor were they convened by a recognized scientific authority. The report is a collection of 17 sections on various topics each authored by 1 to 3 persons from the working group. The research on both ELF and radio frequency (RF) EMF was addressed, with major portions of the report focused largely or entirely on RF research. Epidemiologic literature related to ELF EMF and childhood cancers, Alzheimer’s disease, and breast cancer was discussed, as well as experimental data for a number of mechanistic hypotheses.

## Conclusions and comments

The authors of the BioInitiative Report contended that the standard procedure for developing exposure guidelines—i.e., to set guidelines where adverse health effects have been established by using a weight-of-evidence approach—is not appropriate and should be replaced by a process that sets guidelines at exposure levels where biological effects have been reported in some studies, but not substantiated in a rigorous review of the science or linked to adverse health effects.

Based on this argument, the main conclusion of the BioInitiative Report was that existing standards for exposure to ELF EMF are insufficient because “effects are now widely reported to occur at exposure levels significantly below most current national and international limits” (Table 1-1). Specifically, the authors concluded that there was strong evidence to suggest that magnetic fields were a cause of childhood leukemia based on epidemiologic findings.

The report recommended the following:

*ELF limits should be set below those exposure levels that have been linked in childhood leukemia studies to increased risk of disease, plus an additional safety factor ... While new ELF limits are being developed and implemented, a reasonable approach would be a 1 mG (0.1 µT) planning limit for habitable space adjacent to all new or upgraded power lines and a 2 mG (0.2 µT) limit for all other new construction. It is also recommended that a 1 mG (0.1 µT) limit be established for existing habitable space for children and/or women who are pregnant. (p. 22)*

The recommendations made in the BioInitiative Report are not based on appropriate scientific methods and, therefore, do not warrant any changes to the conclusions from the numerous scientific agencies that have already considered this issue. These organizations are consistent in their conclusions that the research does not support the setting of exposure standards at these low levels of magnetic field exposure.

The World Health Organization (WHO) published the most recent weight-of-evidence review in June 2007 and concluded the following:

*Everyday, low-intensity ELF magnetic field exposure poses a possible increased risk of childhood leukaemia, but the evidence is not strong enough to be considered causal and therefore ELF magnetic fields remain classified as possibly carcinogenic. (p. 357)*

The report continued:

*Given the weakness of the evidence for a link between exposure to ELF magnetic fields and childhood leukaemia and the limited potential impact on public health, the benefits of exposure reduction on health are unclear and thus the cost of reducing exposure should be very low. (p. 372)*

The WHO made no recommendations for exposure standards at the magnetic field levels where an association has been reported in some epidemiologic studies of childhood leukemia. In a fact sheet created for the general public and published on their website, the WHO stated,

*When constructing new facilities and designing new equipment, including appliances, low-cost ways of reducing exposures may be explored...However, policies based on the adoption of arbitrary low exposure limits are not warranted (WHO, 2007b).*

As stated, the conclusions in the BioInitiative Report deviate substantially from those of reputable scientific organizations because they were not based on standard, scientific methods. Valid

scientific conclusions are based on weight-of-evidence reviews, which entail a systematic evaluation of the entire body of scientific evidence in three areas of research (i.e., epidemiology, *in vivo* research, and *in vitro* research), by panels of experts in these relevant disciplines. The report by the BioInitiative working group does not represent a valid weight-of-evidence review for the following key reasons:

1. **Review panels should consist of a multidisciplinary team of experts that reach consensus statements by collaboratively contributing to and reviewing the final work product.** This process ensures that overall conclusions represent a valid and balanced view of each relevant area of research. The document released by the BioInitiative working group was a compilation of sections, with each authored by one to three members of the group. It does not appear that the report was developed collaboratively or reviewed in its entirety by each member.
2. **Valid conclusions about causality are based on systematic evaluations of three lines of evidence—epidemiology, *in vivo* research, and *in vitro* research.** The conclusions in the BioInitiative Report are not based on this multidisciplinary approach. In particular, little attention is provided to the results from *in vivo* studies on cancer and disproportionate weight is given to the results of *in vitro* studies reporting biological effects.
3. **The entire body of evidence to date should be considered when drawing conclusions regarding the strength of evidence in support of a hypothesis.** The BioInitiative Report is not a comprehensive review of the cumulative evidence. Rather, results from specific studies are cited, but no rationale is provided for their inclusion relative to the many other relevant, published studies.
4. **The evidence from each study must be evaluated critically to determine its validity and the degree to which it is relevant and able to support or refute the hypothesis under question.** The significance of the results reported in any study depends on the validity of the methods used in that study, so weight-of-evidence reviews must include an evaluation of the strengths and limitations of each study. In some discussions, the report claimed to use a weight-of-evidence approach, but the individual sections of the report provide little evidence that the strengths and limitations of individual studies (e.g., the quality of exposure assessment, sample size, biases, and confounding factors) were evaluated systematically.

5. **Support for a causal relationship is based on consistent findings from methodologically sound epidemiology studies that are coherent with the results reported from *in vivo* and *in vitro* studies.** The BioInitiative group often arrived at conclusions about causality by considering only a few studies from one discipline, with no consideration of the significance and validity of the study's results.

In summary, the authors of this report largely ignored basic scientific methods that should be followed in the review and evaluation of scientific evidence. These methods are fundamental to scientific inquiry and are not, as the BioInitiative Report states, “unreasonably high.”

The policy responses proposed in the report are cast as consistent with the precautionary principle, i.e., taking action in situations of scientific uncertainty before there is strong proof of harm. A central tenet of the precautionary principle is that precautionary recommendations are proportional to the perceived level of risk and that this perception is founded largely on the weight of the available scientific evidence. The BioInitiative Report recommends precautionary measures on the basis of argument, rather than the basis of sound peer-reviewed scientific evidence.

Unlike the BioInitiative Report, the WHO review was the product of a multidisciplinary scientific panel assembled by an established public health agency that followed appropriate scientific methods, including the systematic and critical examination of all the relevant evidence. The recommendations from the WHO report (pp. 372-373) are presented below:

- *Policy-makers should establish guidelines for ELF field exposure for both the general public and workers. The best source of guidance for both exposure levels and the principles of scientific review are the international guidelines.*
- *Policy-makers should establish an ELF EMF protection programme that includes measurements of fields from all sources to ensure that the exposure limits are not exceeded either for the general public or workers.*
- *Provided that the health, social and economic benefits of electric power are not compromised, implementing very low-cost precautionary procedures to reduce exposures is reasonable and warranted.*

- *Policy-makers and community planners should implement very low-cost measures when constructing new facilities and designing new equipment including appliances.*
- *Changes to engineering practice to reduce ELF exposure from equipment or devices should be considered, provided that they yield other additional benefits, such as greater safety, or involve little or no cost.*
- *When changes to existing ELF sources are contemplated, ELF field reduction should be considered alongside safety, reliability and economic aspects.*
- *Local authorities should enforce wiring regulations to reduce unintentional ground currents when building new or rewiring existing facilities, while maintaining safety. Proactive measures to identify violations or existing problems in wiring would be expensive and unlikely to be justified.*
- *National authorities should implement an effective and open communication strategy to enable informed decision-making by all stakeholders; this should include information on how individuals can reduce their own exposure.*
- *Local authorities should improve planning of ELF EMF-emitting facilities, including better consultation between industry, local government, and citizens when siting major ELF EMF-emitting sources.*
- *Government and industry should promote research programmes to reduce the uncertainty of the scientific evidence on the health effects of ELF field exposure.*

## **Appendix H**

### **Environmental Justice Tables**



# **Environmental Justice Tables for BPA I-5 Corridor Reinforcement Project**

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## **Introduction**

Minority and low-income populations evaluated in these tables represent all block groups crossed by the 150-foot-wide transmission line right-of-way, substation disturbance areas, and access roads (existing, improved and new). Populations were mapped based on the following data sources:

- U.S. Census Block Groups boundary (Environmental Systems Research Institute, Inc. (ESRI)).
- Census 2000 Summary File 1. Detailed Table P4. Hispanic or Latino, and Not Hispanic or Latino by Race.
- Census 2000 Summary File 3. Detailed Table P87. Poverty Status in 1999 by Age.
- Census 2000 Summary File 3. Detailed Table P53. Median Household Income in 1999.

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**Table H-1. Poverty Thresholds in 1999 by Size of Family and Number of Related Children Under 18 Years Old (1999 Dollars)**

Size of Family Unit	Weighted Average Threshold	Related children under 18 years								
		None	One	Two	Three	Four	Five	Six	Seven	Eight or more
One person (unrelated individual)	\$8,501									
Under 65 years old	\$8,667	\$8,667								
65 years old and over	\$7,990	\$7,990								
Two People	\$10,869									
Householder under 65 years old	\$11,214	\$11,156	\$11,483							
Householder 65 years old and over	\$10,075	\$10,070	\$11,440							
Three people	\$13,290	\$13,032	\$13,410	\$13,423						
Four people	\$17,029	\$17,184	\$17,465	\$16,895	\$16,954					
Five people	\$20,127	\$20,723	\$21,024	\$20,380	\$19,882	\$19,578				
Six people	\$22,727	\$23,835	\$23,930	\$23,436	\$22,964	\$22,261	\$21,845			
Seven people	\$25,912	\$27,425	\$27,596	\$27,006	\$26,595	\$25,828	\$24,934	\$23,953		
Eight people	\$28,967	\$30,673	\$30,944	\$30,387	\$29,899	\$29,206	\$28,327	\$27,412	\$27,180	
Nine people or more	\$34,417	\$36,897	\$37,076	\$36,583	\$36,169	\$35,489	\$34,554	\$33,708	\$33,499	\$32,208

Source: U.S. Census Bureau. 2000. American FactFinder Help: Subject Characteristic: Poverty Status in 1999. Accessed January 13, 2011. Available online at: [http://factfinder.census.gov/servlet/MetadataBrowserServlet?type=subject&id=POVERTYSF3&dsspName=DEC\\_2000\\_SF3&back=update&\\_lang=en](http://factfinder.census.gov/servlet/MetadataBrowserServlet?type=subject&id=POVERTYSF3&dsspName=DEC_2000_SF3&back=update&_lang=en)

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**Table H-2. Block Groups Crossed by Route Segments and Substations**

Geographic Area	Route Segment and Substation		
	150-foot Right-of-Way/ Substation Disturbance Area	Improved Access Roads	New Access Roads
Washington	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 14, 15, 18, 23, 25, 26, 28, 30, 35, 36, 36A, 36B, 37, 38, 39, 40, 41, 43, 45, 46, 47, 48, 49, 50, 51, 52, A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, Baxter Creek Substation, Casey Road Substation, Monahan Creek Substation	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 14, 15, 18, 23, 25, 26, 28, 30, 35, 36A, 36B, 37, 38, 39, 40, 41, 43, 45, 46, 47, 49, 50, 51, 52, A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, Baxter Creek Substation, Casey Road Substation	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 14, 15, 18, 23, 25, 26, 28, 30, 35, 36A, 36B, 37, 38, 39, 40, 41, 43, 45, 46, 47, 48, 49, 50, 51, 52, A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P, Q, R, S, T, U, V, W, Baxter Creek Substation, Casey Road Substation, Monahan Creek Substation
Cowlitz County	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 14, 15, 23, 25, A, B, C, D, E, F, G, H, I, J, K, L, M, Baxter Creek Substation, Casey Road Substation, Monahan Creek Substation	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 14, 15, 23, 25, A, B, C, D, E, F, G, H, I, J, K, Baxter Creek Substation, Casey Road Substation	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 14, 15, 23, 25, A, B, C, D, E, F, G, H, I, J, K, L, M, Baxter Creek Substation, Casey Road Substation, Monahan Creek Substation
Census Tract 09, Block Group 1	1, 2	1, 2	1, 2
Census Tract 09, Block Group 2	1, 2, 4	1, 2, 4	1, 2, 4
Census Tract 09, Block Group 3	1	--	--
Census Tract 09, Block Group 4	1	1, 4	1
Census Tract 12, Block Group 1	9	9	9
Census Tract 12, Block Group 2	9	9	9
Census Tract 12, Block Group 3	9	9	9
Census Tract 13, Block Group 1	3, 5, 9	3, 5, 7, 9	3, 5, 9
Census Tract 13, Block Group 2	4, 5, 9	4, 5, 9	--
Census Tract 15, Block Group 6	9, 10, 12, 14, 15, 23, 25, L, M	9, 10, 12, 14, 15, 23, 25	9, 10, 12, 14, 15, 23, 25, L, M
Census Tract 15, Block Group 7	K	K	K
Census Tract 16, Block Group 1	--	9	9
Census Tract 17, Block Group 1	3	3	3
Census Tract 17, Block Group 2	3, 7, 8, F	3, 7, 8, 11, F	7, F

**Table H-2. Block Groups Crossed by Route Segments and Substations (continued)**

Geographic Area	Route Segment and Substation		
	150-foot Right-of-Way/ Substation Disturbance Area	Improved Access Roads	New Access Roads
Census Tract 17, Block Group 3	3, 5, 7, 8, 11, F	3, 7, 8, 11, F	3, 5, 7, 8, 11, F
Census Tract 17, Block Group 4	9, 10, 11, F, G, H, I, J, K	9, 10, 11, F, G, H, I, J, K	9, 10, 11, F, G, H, I, J, K
Census Tract 17, Block Group 5	9	9	9
Census Tract 18, Block Group 2	K	K	K
Census Tract 19, Block Group 4	1, 2, 3, E, Monahan Creek Substation	1, 2, 3, E,	1, 2, 3, E, Monahan Creek Substation
Census Tract 20.01, Block Group 1	A, C, D, E, Baxter Creek Substation, Casey Road Substation	A, B, C, D, Baxter Creek Substation, Casey Road Substation	A, C, D, E, Baxter Creek Substation, Casey Road Substation
Census Tract 20.01, Block Group 2	A, B, C, D, F, Baxter Creek Substation	A, B, C, D, F, Baxter Creek Substation	A, B, C, D, F, Baxter Creek Substation
Census Tract 20.01, Block Group 3	3	3	3
Census Tract 20.01, Block Group 4	3, C, D, E	2, 3, C, D, E	3, C, D, E
Census Tract 20.02, Block Group 1	F	F	F
Census Tract 20.02, Block Group 5	F	F	F
<b>Clark County</b>	18, 25, 26, 28, 30, 35, 36, 36A, 36B, 37, 38, 39, 40, 41, 43, 45, 46, 47, 48, 49, 50, 51, 52, K, L, M, N, O, P, Q, R, S, T, U, V, W	18, 25, 26, 28, 30, 35, 36A, 36B, 37, 38, 39, 40, 41, 43, 45, 46, 47, 49, 50, 51, 52, K, L, M, N, O, P, Q, R, S, T, U, V, W	18, 25, 26, 28, 30, 35, 36A, 36B, 37, 38, 39, 40, 41, 43, 45, 46, 47, 48, 49, 50, 51, 52, K, L, M, N, O, P, Q, R, S, T, U, V, W
Census Tract 401.01, Block Group 1	18, 26, 28, L, M, N	18, 26, 28, K, L, M, N, W	18, 26, 28, L, M, N
Census Tract 401.01, Block Group 2	28, K, N, O, U, V, W	18, 28, K, N, O, U, V, W	28, K, N, O, U, V, W
Census Tract 401.02, Block Group 1	26	--	26
Census Tract 401.02, Block Group 2	26, 30	26, 30	26, 30
Census Tract 402.01, Block Group 1	25	--	25
Census Tract 402.01, Block Group 2	25	--	25
Census Tract 402.02, Block Group 1	25, L, M	26, M	25, L, M
Census Tract 402.02, Block Group 2	25	25	25

**Table H-2. Block Groups Crossed by Route Segments and Substations (continued)**

<b>Geographic Area</b>	<b>Route Segment and Substation</b>		
	<b>150-foot Right-of-Way/ Substation Disturbance Area</b>	<b>Improved Access Roads</b>	<b>New Access Roads</b>
Census Tract 402.03, Block Group 3	25	25	25
Census Tract 404.03, Block Group 1	25	25	25
Census Tract 404.03, Block Group 2	25	--	25
Census Tract 404.04, Block Group 2	25	25	25
Census Tract 405.04, Block Group 1	30, O, V	30, O, V	30, O, P, V
Census Tract 405.04, Block Group 2	30, P, V	30, P, V	30, P, V
Census Tract 405.04, Block Group 3	P	P	P
Census Tract 405.06, Block Group 1	35, 39, O, P, Q, R	35, 39, O, P, Q, R	35, O, P, Q, R
Census Tract 405.06, Block Group 2	35, 39, 48, 49, 51, Q, R, S, T	35, 39, 49, 51, Q, R, S, T	35, 39, 48, 49, 51, Q, R, S, T
Census Tract 405.06, Block Group 3	50, 51, 52	50, 51, 52	50, 51, 52
Census Tract 406.03, Block Group 4	39, 48	39	39, 48
Census Tract 406.04, Block Group 2	37, 38, 39, 40, 41, 43, 36A, 36B	37, 38, 39, 40, 41, 43, 36A, 36B	37, 38, 39, 40, 41, 43, 36A, 36B
Census Tract 406.05, Block Group 1	48, 50, 51, 52	50, 51	48, 50, 51, 52
Census Tract 406.05, Block Group 2	41, 43, 45, 46, 47, 48, 50	41, 43, 45, 46, 47, 50	41, 43, 45, 46, 47, 48, 50
Census Tract 406.06, Block Group 1	40, 46	40, 46	40, 46
Census Tract 407.03, Block Group 3	25	--	25
Census Tract 407.03, Block Group 4	25	--	25
Census Tract 407.06, Block Group 1	25	--	25
Census Tract 408.03, Block Group 2	25	--	25
Census Tract 408.03, Block Group 3	25	--	25
Census Tract 408.04, Block Group 2	25	25	25
Census Tract 408.05, Block Group 1	25	25	25

**Table H-2. Block Groups Crossed by Route Segments and Substations (continued)**

<b>Geographic Area</b>	<b>Route Segment and Substation</b>		
	<b>150-foot Right-of-Way/ Substation Disturbance Area</b>	<b>Improved Access Roads</b>	<b>New Access Roads</b>
Census Tract 410.02, Block Group 1	25	25	25
Census Tract 410.02, Block Group 2	25	25	25
Census Tract 410.02, Block Group 3	25	25	25
Census Tract 411.04, Block Group 1	25	25	25
Census Tract 411.04, Block Group 2	25	--	25
Census Tract 411.05, Block Group 1	25	--	25
Census Tract 411.05, Block Group 3	25	--	25
Census Tract 411.07, Block Group 1	25	--	25
Census Tract 413.12, Block Group 2	25	--	25
Census Tract 413.15, Block Group 1	25	25	25
Census Tract 413.15, Block Group 2	25, 36, 40, 36A, 36B	25, 40, 36A, 36B	25, 40, 36A, 36B
Census Tract 413.21, Block Group 2	40	--	40
Census Tract 414, Block Group 3	52	52	52
Census Tract 415, Block Group 1	52	52	52
Census Tract 415, Block Group 2	52	--	52
<b>Oregon</b>	52, Sundial Substation	--	52, Sundial Substation
<b>Multnomah County</b>	52, Sundial Substation	--	52, Sundial Substation
Census Tract 102, Block Group 1	52, Sundial Substation	--	52, Sundial Substation

**Source:**  
U.S. Census Bureau. 2000a. Census 2000 Summary File 1, Detailed Table P4. Accessed January 19, 2011.  
Available online at <http://factfinder.census.gov/>.  
U.S. Census Bureau. 2000b. Census 2000 Summary File 3, Detailed Table P87. Accessed January 19, 2011.  
Available online at <http://factfinder.census.gov/>.  
U.S. Census Bureau. 2000c. Census 2000 Summary File 3. Detailed Table P53. Accessed January 19, 2011.  
Available online at <http://factfinder.census.gov/>.

**Table H-3. Race and Ethnicity by Block Group, County and State**

Geographic Area	Total Population	Percent of Total Population						Two or more races	Minority Population ?
		White	American Indian or Alaskan Native	Asian or Pacific Islander	Black or African American	Hispanic or Latino	Some other race alone		
<b>Washington State</b>	<b>5,894,121</b>	<b>78.9</b>	<b>1.4</b>	<b>5.8</b>	<b>3.1</b>	<b>7.5</b>	<b>0.2</b>	<b>3.0</b>	<b>No</b>
<b>Cowlitz County</b>	<b>92,948</b>	<b>89.9</b>	<b>1.4</b>	<b>1.4</b>	<b>0.5</b>	<b>4.6</b>	<b>0.1</b>	<b>2.2</b>	<b>No</b>
Block Group 1, Census Tract 9	670	96.3	1.3	0.1	0.3	0.4	0.0	1.5	No
Block Group 2, Census Tract 9	2,228	92.4	1.3	1.5	0.3	2.2	0.0	2.3	No
Block Group 3, Census Tract 9	1,273	95.5	0.2	0.9	0.5	1.7	0.2	0.9	No
Block Group 4, Census Tract 9	1,702	93.5	1.0	1.0	0.2	2.2	0.0	2.1	No
Block Group 1, Census Tract 12	933	92.9	0.3	0.5	0.5	2.8	0.3	2.6	No
Block Group 2, Census Tract 12	962	93.5	0.9	0.2	0.7	3.3	0.0	1.4	No
Block Group 3, Census Tract 12	1,232	95.5	0.9	0.2	0.3	1.8	0.0	1.4	No
Block Group 1, Census Tract 13	941	90.2	1.7	0.4	0.2	5.2	0.0	2.2	No
Block Group 2, Census Tract 13	1,075	87.1	2.2	0.6	0.5	6.8	0.1	2.8	No
Block Group 6, Census Tract 15	1,497	91.7	1.3	0.8	0.1	3.2	0.5	2.5	No
Block Group 7, Census Tract 15	808	96.4	0.7	0.5	0.1	1.0	0.0	1.2	No
Block Group 1, Census Tract 16	740	93.6	1.4	0.3	0.1	3.0	0.0	1.6	No
Block Group 1, Census Tract 17	549	94.0	1.6	0.7	0.0	1.1	0.0	2.6	No
Block Group 2, Census Tract 17	871	89.9	2.2	0.9	0.5	2.3	0.0	4.2	No
Block Group 3, Census Tract 17	557	96.6	0.5	0.5	0.0	0.9	0.2	1.3	No
Block Group 4, Census Tract 17	916	92.6	1.6	0.9	0.0	1.6	0.0	3.3	No
Block Group 5, Census Tract 17	1,761	93.7	1.2	0.5	0.0	2.5	0.0	2.2	No
Block Group 2, Census Tract 18	734	91.4	0.7	0.5	0.1	3.8	0.0	3.4	No
Block Group 4, Census Tract 19	1,598	93.7	1.0	0.4	0.3	1.6	0.5	2.4	No
Block Group 1, Census Tract 20.01	885	94.2	0.6	0.7	0.9	1.9	0.1	1.6	No
Block Group 2, Census Tract 20.01	923	95.0	0.9	0.9	0.0	1.3	0.0	2.0	No
Block Group 3, Census Tract 20.01	868	95.2	1.3	0.5	0.5	1.2	0.0	1.5	No
Block Group 4, Census Tract 20.01	660	92.1	0.6	1.1	0.2	3.9	0.0	2.1	No

**Table H-3. Race and Ethnicity by Block Group, County and State (continued)**

Geographic Area	Total Population	Percent of Total Population						Two or more races	Minority Population ?
		White	American Indian or Alaskan Native	Asian or Pacific Islander	Black or African American	Hispanic or Latino	Some other race alone		
Block Group 1, Census Tract 20.02	1,348	94.8	0.6	0.4	0.1	1.8	0.0	2.3	No
Block Group 5, Census Tract 20.02	964	93.6	1.5	0.5	0.2	2.0	0.0	2.3	No
<b>Clark County</b>	<b>345,238</b>	<b>86.6</b>	<b>0.7</b>	<b>3.5</b>	<b>1.6</b>	<b>4.7</b>	<b>0.1</b>	<b>2.6</b>	<b>No</b>
Block Group 1, Census Tract 401.01	1,606	94.7	0.9	0.6	0.6	1.7	0.1	1.4	No
Block Group 2, Census Tract 401.01	2,116	92.3	1.1	0.8	0.3	2.2	0.2	3.1	No
Block Group 1, Census Tract 401.02	1,048	94.2	0.3	1.0	0.5	2.5	0.0	1.6	No
Block Group 2, Census Tract 401.02	1,905	94.0	0.6	0.4	0.2	1.9	0.3	2.6	No
Block Group 1, Census Tract 402.01	2,471	92.4	0.3	0.8	0.1	4.5	0.2	1.7	No
Block Group 2, Census Tract 402.01	2,157	90.6	0.6	1.1	0.5	4.6	0.0	2.6	No
Block Group 1, Census Tract 402.02	1,507	93.3	0.7	1.3	0.3	2.2	0.2	2.0	No
Block Group 2, Census Tract 402.02	1,717	93.8	1.0	0.5	0.4	2.5	0.2	1.6	No
Block Group 3, Census Tract 402.03	1,660	93.1	0.4	1.2	0.0	3.1	0.4	1.7	No
Block Group 1, Census Tract 404.03	2,076	93.2	0.9	1.0	0.4	1.7	0.0	2.8	No
Block Group 2, Census Tract 404.03	1,629	93.0	0.7	1.2	0.8	1.4	0.0	3.0	No
Block Group 2, Census Tract 404.04	2,054	92.2	0.4	2.6	0.5	2.4	0.1	1.7	No
Block Group 1, Census Tract 405.04	2,027	91.3	0.6	0.8	4.1	2.4	0.0	0.8	No
Block Group 2, Census Tract 405.04	1,281	94.1	0.3	0.4	0.1	2.6	0.2	2.3	No
Block Group 3, Census Tract 405.04	819	95.0	1.5	1.1	0.0	1.2	0.0	1.2	No
Block Group 1, Census Tract 405.06	845	94.1	0.4	1.8	0.2	1.5	0.2	1.8	No
Block Group 2, Census Tract 405.06	1,861	94.3	0.7	0.6	0.1	2.6	0.1	1.6	No
Block Group 3, Census Tract 405.06	1,449	94.2	0.5	0.6	0.1	1.7	0.6	2.3	No
Block Group 4, Census Tract 406.03	1,160	94.3	0.2	2.0	0.2	1.8	0.0	1.6	No
Block Group 2, Census Tract 406.04	520	93.1	0.4	1.2	0.0	3.5	0.0	1.9	No
Block Group 1, Census Tract 406.05	1,526	95.6	0.5	0.3	0.0	2.6	0.0	1.0	No
Block Group 2, Census Tract 406.05	919	95.3	0.7	0.2	0.2	2.3	0.0	1.3	No

**Table H-3. Race and Ethnicity by Block Group, County and State (continued)**

Geographic Area	Total Population	Percent of Total Population						Two or more races	Minority Population ?
		White	American Indian or Alaskan Native	Asian or Pacific Islander	Black or African American	Hispanic or Latino	Some other race alone		
Block Group 1, Census Tract 406.06	836	89.0	0.7	4.9	1.6	3.0	0.1	0.7	No
Block Group 3, Census Tract 407.03	1,105	80.0	0.8	8.4	1.5	7.1	0.0	2.2	No
Block Group 4, Census Tract 407.03	1,098	83.8	0.9	6.7	1.9	4.6	0.0	2.1	No
Block Group 1, Census Tract 407.06	1,983	81.5	1.0	5.2	2.1	6.5	0.1	3.6	No
Block Group 2, Census Tract 408.03	1,921	94.1	0.2	2.1	0.6	1.8	0.0	1.2	No
Block Group 3, Census Tract 408.03	700	91.9	0.1	1.9	1.4	0.9	0.0	3.9	No
Block Group 2, Census Tract 408.04	2,823	89.3	0.4	3.5	1.3	3.5	0.1	1.8	No
Block Group 1, Census Tract 408.05	2,230	92.6	0.4	2.8	0.4	2.2	0.2	1.3	No
Block Group 1, Census Tract 410.02	1,488	86.4	1.1	1.4	3.4	4.6	0.3	2.8	No
Block Group 2, Census Tract 410.02	1,887	83.4	1.1	2.3	4.1	5.4	0.0	3.8	No
Block Group 3, Census Tract 410.02	1,792	86.5	1.7	2.5	1.8	4.4	0.2	2.8	No
Block Group 1, Census Tract 411.04	1,377	86.9	0.9	4.9	1.7	3.8	0.1	1.7	No
Block Group 2, Census Tract 411.04	1,183	83.6	0.7	4.0	3.0	4.7	0.5	3.5	No
Block Group 1, Census Tract 411.05	2,110	89.4	0.7	2.2	2.1	3.7	0.1	1.8	No
Block Group 3, Census Tract 411.05	839	90.0	1.1	3.5	0.2	2.3	0.4	2.6	No
Block Group 1, Census Tract 411.07	1,687	90.0	0.8	4.7	0.8	1.7	0.0	2.1	No
Block Group 2, Census Tract 413.12	1,260	87.3	0.7	2.7	2.6	4.4	0.2	2.1	No
Block Group 1, Census Tract 413.15	2,355	83.6	0.5	5.3	2.2	4.9	0.1	3.4	No
Block Group 2, Census Tract 413.15	3,558	86.5	0.7	6.5	0.7	2.5	0.1	3.0	No
Block Group 2, Census Tract 413.21	717	87.7	0.1	5.2	2.2	1.4	0.0	3.3	No
Block Group 3, Census Tract 414	1,913	91.4	0.5	1.6	0.7	2.7	0.0	3.1	No
Block Group 1, Census Tract 415	906	93.7	0.3	0.9	0.3	3.2	0.1	1.4	No
Block Group 2, Census Tract 415	722	89.3	0.0	0.6	1.5	5.8	0.0	2.8	No

**Table H-3. Race and Ethnicity by Block Group, County and State (continued)**

Geographic Area	Total Population	Percent of Total Population						Two or more races	Minority Population ?
		White	American Indian or Alaskan Native	Asian or Pacific Islander	Black or African American	Hispanic or Latino	Some other race alone		
Oregon State	3,421,399	83.5	1.2	3.1	1.6	8.0	0.1	2.4	No
Multnomah County	660,486	76.5	0.9	6.0	5.5	7.5	0.2	3.4	No
Block Group 1, Census Tract 102	2,927	85.3	1.2	4.3	1.6	4.0	0.5	3.1	No

Notes:

1. These data compiled as part of the 2000 Census are the most recent available data at the census block group level.
2. Minority populations are identified if the minority population is greater than 50 percent or meaningfully greater than the state's minority percent.

Sources: U.S. Census Bureau. 2000. Census 2000 Summary File 1, Detailed Table P4. Accessed January 19, 2011. Available online at <http://factfinder.census.gov/>.

**Table H-4. Low-Income Populations by Block Group, County and State<sup>1</sup>**

<b>Geographic Area</b>	<b>Total Population</b>	<b>Median Household Income (\$)</b>	<b>Median Household Income (% of State Median)</b>	<b>Total Population below the Poverty Level</b>	<b>% of Population below the Poverty Level</b>	<b>Low-Income Population?<sup>2</sup></b>
<b>Washington State</b>	<b>5,765,201</b>	<b>45,776</b>	<b>N/A</b>	<b>612,370</b>	<b>10.6</b>	<b>No</b>
<b>Cowlitz County</b>	<b>91,364</b>	<b>39,797</b>	<b>87</b>	<b>12,765</b>	<b>14.0</b>	<b>No</b>
Block Group 1, Census Tract 9	687	27,625	60	108	15.7	No
Block Group 2, Census Tract 9	2,215	51,016	111	248	11.2	No
Block Group 3, Census Tract 9	1,277	45,714	100	82	6.4	No
Block Group 4, Census Tract 9	1,568	51,467	112	190	12.1	No
Block Group 1, Census Tract 12	935	44,271	97	41	4.4	No
Block Group 2, Census Tract 12	970	36,281	79	117	12.1	No
Block Group 3, Census Tract 12	1,201	56,208	123	161	13.4	No
Block Group 1, Census Tract 13	848	37,969	83	60	7.1	No
Block Group 2, Census Tract 13	1,033	37,738	82	152	14.7	No
Block Group 6, Census Tract 15	1,521	52,500	115	29	1.9	No
Block Group 7, Census Tract 15	714	33,889	74	137	19.2	No
Block Group 1, Census Tract 16	706	52,150	114	107	15.2	No
Block Group 1, Census Tract 17	535	46,250	101	67	12.5	No
Block Group 2, Census Tract 17	870	50,045	109	25	2.9	No
Block Group 3, Census Tract 17	525	54,107	118	6	1.1	No
Block Group 4, Census Tract 17	926	53,173	116	167	18.0	No
Block Group 5, Census Tract 17	1,779	54,864	120	65	3.7	No
Block Group 2, Census Tract 18	687	40,789	89	89	13.0	No
Block Group 4, Census Tract 19	1,551	52,768	115	120	7.7	No
Block Group 1, Census Tract 20.01	904	28,984	63	88	9.7	No

**Table H-4. Low-Income Populations by Block Group, County and State<sup>1</sup>(continued)**

<b>Geographic Area</b>	<b>Total Population</b>	<b>Median Household Income (\$)</b>	<b>Median Household Income (% of State Median)</b>	<b>Total Population below the Poverty Level</b>	<b>% of Population below the Poverty Level</b>	<b>Low-Income Population?<sup>2</sup></b>
Block Group 2, Census Tract 20.01	907	50,147	110	33	3.6	No
Block Group 3, Census Tract 20.01	900	43,333	95	58	6.4	No
Block Group 4, Census Tract 20.01	625	46,563	102	13	2.1	No
Block Group 1, Census Tract 20.02	1,293	44,063	96	16	1.2	No
Block Group 5, Census Tract 20.02	921	51,146	112	66	7.2	No
<b>Clark County</b>	<b>341,464</b>	<b>48,376</b>	<b>106</b>	<b>31,027</b>	<b>9.1</b>	<b>No</b>
Block Group 1, Census Tract 401.01	1,611	46,012	101	180	11.2	No
Block Group 2, Census Tract 401.01	2,096	45,452	99	211	10.1	No
Block Group 1, Census Tract 401.02	1,041	75,097	164	15	1.4	No
Block Group 2, Census Tract 401.02	1,902	48,077	105	144	7.6	No
Block Group 1, Census Tract 402.01	2,434	48,125	105	156	6.4	No
Block Group 2, Census Tract 402.01	2,148	52,355	114	99	4.6	No
Block Group 1, Census Tract 402.02	1,503	46,313	101	113	7.5	No
Block Group 2, Census Tract 402.02	1,683	55,446	121	135	8.0	No
Block Group 3, Census Tract 402.03	1,597	59,293	130	88	5.5	No
Block Group 1, Census Tract 404.03	1,994	64,931	142	37	1.9	No
Block Group 2, Census Tract 404.03	1,711	50,000	109	124	7.2	No
Block Group 2, Census Tract 404.04	2,168	68,260	149	5	0.2	No
Block Group 1, Census Tract 405.04	1,601	57,125	125	90	5.6	No
Block Group 2, Census Tract 405.04	1,330	61,375	134	52	3.9	No
Block Group 3, Census Tract 405.04	807	56,094	123	83	10.3	No
Block Group 1, Census Tract 405.06	891	93,128	203	0	0.0	No

**Table H-4. Low-Income Populations by Block Group, County and State<sup>1</sup>(continued)**

<b>Geographic Area</b>	<b>Total Population</b>	<b>Median Household Income (\$)</b>	<b>Median Household Income (% of State Median)</b>	<b>Total Population below the Poverty Level</b>	<b>% of Population below the Poverty Level</b>	<b>Low-Income Population?<sup>2</sup></b>
Block Group 2, Census Tract 405.06	1,834	54,904	120	87	4.7	No
Block Group 3, Census Tract 405.06	1,458	56,563	124	7	0.5	No
Block Group 4, Census Tract 406.03	1,165	66,324	145	63	5.4	No
Block Group 2, Census Tract 406.04	512	44,875	98	0	0.0	No
Block Group 1, Census Tract 406.05	1,560	53,813	118	80	5.1	No
Block Group 2, Census Tract 406.05	899	62,188	136	31	3.4	No
Block Group 1, Census Tract 406.06	811	100,449	219	52	6.4	No
Block Group 3, Census Tract 407.03	1,091	50,380	110	49	4.5	No
Block Group 4, Census Tract 407.03	1,106	33,462	73	192	17.4	No
Block Group 1, Census Tract 407.06	1,973	38,415	84	243	12.3	No
Block Group 2, Census Tract 408.03	1,977	75,131	164	50	2.5	No
Block Group 3, Census Tract 408.03	700	63,438	139	8	1.1	No
Block Group 2, Census Tract 408.04	2,855	62,008	135	119	4.2	No
Block Group 1, Census Tract 408.05	2,283	75,817	166	42	1.8	No
Block Group 1, Census Tract 410.02	1,402	22,963	50	328	23.4	Yes
Block Group 2, Census Tract 410.02	1,927	39,817	87	199	10.3	No
Block Group 3, Census Tract 410.02	1,800	44,063	96	170	9.4	No
Block Group 1, Census Tract 411.04	1,308	48,156	105	132	10.1	No
Block Group 2, Census Tract 411.04	1,230	46,908	102	79	6.4	No
Block Group 1, Census Tract 411.05	2,098	44,255	97	299	14.3	No
Block Group 3, Census Tract 411.05	813	53,287	116	0	0.0	No
Block Group 1, Census Tract 411.07	1,763	64,333	141	37	2.1	No

**Table H-4. Low-Income Populations by Block Group, County and State<sup>1</sup>(continued)**

<b>Geographic Area</b>	<b>Total Population</b>	<b>Median Household Income (\$)</b>	<b>Median Household Income (% of State Median)</b>	<b>Total Population below the Poverty Level</b>	<b>% of Population below the Poverty Level</b>	<b>Low-Income Population?<sup>2</sup></b>
Block Group 2, Census Tract 413.12	1,231	37,788	83	218	17.7	No
Block Group 1, Census Tract 413.15	2,344	57,891	126	168	7.2	No
Block Group 2, Census Tract 413.15	3,505	62,159	136	411	11.7	No
Block Group 2, Census Tract 413.21	741	64,531	141	73	9.9	No
Block Group 3, Census Tract 414	1,870	50,000	109	131	7.0	No
Block Group 1, Census Tract 415	920	38,600	84	66	7.2	No
Block Group 2, Census Tract 415	696	40,536	89	119	17.1	No
<b>Oregon State</b>	<b>3,347,667</b>	<b>40,916</b>	<b>N/A</b>	<b>388,740</b>	<b>11.6</b>	<b>No</b>
<b>Multnomah County</b>	<b>645,584</b>	<b>41,278</b>	<b>101</b>	<b>81,711</b>	<b>12.7</b>	<b>No</b>
Block Group 1, Census Tract 102	2,902	54,875	134	344	11.9	No

Notes:

1. These data compiled as part of the 2000 Census are the most recent available data at the census block group level. The total population in this table is based on summary file 3, which is a sample of the population, and is less than the total population presented in Table 2-2.
2. Low-income populations are identified if the percent of the population below the poverty level is equal to or greater than 20 percent of the total population.

Sources:

U.S. Census Bureau 2000: Census 2000 Summary File 3, Detailed Table P87, Accessed January 19, 2011, Available online at <http://factfinder.census.gov/>; U.S. Census Bureau 2000, Census 2000 Summary File 3, Detailed Table P53, Accessed January 19, 2011, Available online at <http://factfinder.census.gov/>;

**Table H-5. Minority and Low-Income Populations, by Action Alternative**

Geographic Area	Alternatives and Options			Minority Population <sup>1</sup>	Low-Income Population <sup>1</sup>
	150-foot Right-of-Way/ Substation Disturbance Area	Improved Access Roads	New Access Roads		
<b>Washington</b>	--	--	--	No	No
<b>Cowlitz County</b>	--	--	--	No	No
Census Tract 09, Block Group 1	West Alternative, Central Option 2 (+), Crossover Alternative	West Alternative, Central Option 2 (+), Crossover Alternative	West Alternative, Central Option 2 (+), Crossover Alternative	No	No
Census Tract 09, Block Group 2	West Alternative, Central Option 2 (+), Crossover Alternative	West Alternative, Central Option 2 (+), Crossover Alternative	West Alternative, Central Option 2 (+), Crossover Alternative	No	No
Census Tract 09, Block Group 3	Central Option 2 (+)	--	--	No	No
Census Tract 09, Block Group 4	Central Option 2 (+)	West Alternative, Central Option 2 (+), Crossover Alternative	Central Option 2 (+)	No	No
Census Tract 12, Block Group 1	West Alternative, Crossover Alternative	West Alternative, Crossover Alternative	West Alternative, Crossover Alternative	No	No
Census Tract 12, Block Group 2	West Alternative, Crossover Alternative	West Alternative, Crossover Alternative	West Alternative, Crossover Alternative	No	No
Census Tract 12, Block Group 3	West Alternative, Crossover Alternative	West Alternative, Crossover Alternative	West Alternative, Crossover Alternative	No	No
Census Tract 13, Block Group 1	West Alternative, Central Option 2 (+), East Option 1 (+), Crossover Alternative	West Alternative, Central Option 2 (+), East Option 1 (+), Crossover Alternative	West Alternative, Central Option 2 (+), East Option 1 (+), Crossover Alternative	No	No
Census Tract 13, Block Group 2	West Alternative, Central Option 2 (+), Crossover Alternative	West Alternative, Central Option 2 (+), Crossover Alternative	--	No	No

**Table H-5. Minority and Low-Income Populations, by Action Alternative (continued)**

Geographic Area	Alternatives and Options			Minority Population <sup>1</sup>	Low-Income Population <sup>1</sup>
	150-foot Right-of-Way/ Substation Disturbance Area	Improved Access Roads	New Access Roads		
Census Tract 15, Block Group 6	West Alternative, Central Alternative, Central Option 3 (N/C), Crossover Alternative	West Alternative, Central Alternative, Crossover Alternative	West Alternative, Central Alternative, Central Option 3 (N/C), Crossover Alternative	No	No
Census Tract 15, Block Group 7	East Alternative	East Alternative	East Alternative	No	No
Census Tract 16, Block Group 1	--	West Alternative, Crossover Alternative	West Alternative, Crossover Alternative	No	No
Census Tract 17, Block Group 1	East Option 1 (+)	East Option 1 (+)	East Option 1 (+)	No	No
Census Tract 17, Block Group 2	Central Alternative, Central Option 2 (N/C), East Alternative, East Option 1 (N/C)	Central Alternative, Central Option 2 (N/C), East Alternative, East Option 1 (N/C)	Central Alternative, Central Option 2 (-), East Alternative, East Option 1 (N/C)	No	No
Census Tract 17, Block Group 3	Central Alternative, Central Option 2 (N/C), East Alternative, East Option 1 (N/C)	Central Alternative, Central Option 2 (N/C), East Alternative, East Option 1 (N/C)	Central Alternative, Central Option 2 (N/C), East Alternative, East Option 1 (N/C)	No	No
Census Tract 17, Block Group 4	West Alternative, Central Alternative, Central Option 2 (N/C), East Alternative, East Option 1 (N/C), Crossover Alternative	West Alternative, Central Alternative, Central Option 2 (N/C), East Alternative, East Option 1 (N/C), Crossover Alternative	West Alternative, Central Alternative, Central Option 2 (N/C), East Alternative, East Option 1 (N/C), Crossover Alternative	No	No
Census Tract 17, Block Group 5	West Alternative, Crossover Alternative	West Alternative, Crossover Alternative	West Alternative, Crossover Alternative	No	No
Census Tract 18, Block Group 2	East Alternative	East Alternative	East Alternative	No	No

**Table H-5. Minority and Low-Income Populations, by Action Alternative (continued)**

Geographic Area	Alternatives and Options			Minority Population <sup>1</sup>	Low-Income Population <sup>1</sup>
	150-foot Right-of-Way/ Substation Disturbance Area	Improved Access Roads	New Access Roads		
Census Tract 19, Block Group 4	West Alternative, Central Option 2 (+), East Option 1 (+), Crossover Alternative, Crossover Option 2 (N/C), Crossover Option 3 (N/C)	West Alternative, Central Option 2 (+), East Option 1 (+), Crossover Alternative, Crossover Option 2 (N/C), Crossover Option 3 (N/C)	West Alternative, Central Option 2 (+), East Option 1 (+), Crossover Alternative, Crossover Option 2 (N/C), Crossover Option 3 (N/C)	No	No
Census Tract 20.01, Block Group 1	Central Alternative, Central Option 1 (N/C), Central Option 2 (-), East Alternative, East Option 1 (-), Crossover Option 2 (+), Crossover Option 3 (+)	Central Alternative, Central Option 1 (N/C), Central Option 2 (-), East Alternative, East Option 1 (-), Crossover Option 2 (+), Crossover Option 3 (+)	Central Alternative, Central Option 1 (N/C), Central Option 2 (-), East Alternative, East Option 1 (-), Crossover Option 2 (+), Crossover Option 3 (+)	No	No
Census Tract 20.01, Block Group 2	Central Alternative, Central Option 1 (N/C), Central Option 2 (-), East Alternative, East Option 1 (-), Crossover Option 2 (+), Crossover Option 3 (+)	Central Alternative, Central Option 1 (N/C), Central Option 2 (-), East Alternative, East Option 1 (-), Crossover Option 2 (+), Crossover Option 3 (+)	Central Alternative, Central Option 1 (N/C), Central Option 2 (-), East Alternative, East Option 1 (-), Crossover Option 2 (+), Crossover Option 3 (+)	No	No
Census Tract 20.01, Block Group 3	East Option 1 (+)	East Option 1 (+)	East Option 1 (+)	No	No
Census Tract 20.01, Block Group 4	East Option 1 (+), Crossover Option 2 (+), Crossover Option 3 (+)	West Alternative, East Option 1 (+), Crossover Alternative, Crossover Option 2 (N/C), Crossover Option 3 (N/C)	East Option 1 (+), Crossover Option 2 (+), Crossover Option 3 (+)	No	No

**Table H-5. Minority and Low-Income Populations, by Action Alternative (continued)**

Geographic Area	Alternatives and Options			Minority Population <sup>1</sup>	Low-Income Population <sup>1</sup>
	150-foot Right-of-Way/ Substation Disturbance Area	Improved Access Roads	New Access Roads		
Census Tract 20.02, Block Group 1	Central Alternative, Central Option 2 (-), East Alternative, East Option 1 (-)	Central Alternative, Central Option 2 (-), East Alternative, East Option 1 (-)	Central Alternative, Central Option 2 (-), East Alternative, East Option 1 (-)	No	No
Census Tract 20.02, Block Group 5	Central Alternative, Central Option 2 (-), East Alternative, East Option 1 (-)	Central Alternative, Central Option 2 (-), East Alternative, East Option 1 (-)	Central Alternative, Central Option 2 (-), East Alternative, East Option 1 (-)	No	No
<b>Clark County</b>	--	--	--	<b>No</b>	<b>No</b>
Census Tract 401.01, Block Group 1	Central Alternative, Central Option 3 (N/C), Crossover Alternative	Central Alternative, Central Option 3 (N/C), East Alternative, Crossover Alternative	Central Alternative, Central Option 3 (N/C), Crossover Alternative	No	No
Census Tract 401.01, Block Group 2	Central Alternative, Central Option 3 (-), East Alternative, East Option 2 (N/C), Crossover Alternative	Central Alternative, Central Option 3 (-), East Alternative, East Option 2 (N/C), Crossover Alternative	Central Alternative, Central Option 3 (-), East Alternative, East Option 2 (N/C), Crossover Alternative	No	No
Census Tract 401.02, Block Group 1	Central Option 3 (+)	--	Central Option 3 (+)	No	No
Census Tract 401.02, Block Group 2	Central Option 3 (+)	Central Option 3 (+)	Central Option 3 (+)	No	No
Census Tract 402.01, Block Group 1	West Alternative	--	West Alternative	No	No
Census Tract 402.01, Block Group 2	West Alternative	--	West Alternative	No	No

**Table H-5. Minority and Low-Income Populations, by Action Alternative (continued)**

Geographic Area	Alternatives and Options			Minority Population <sup>1</sup>	Low-Income Population <sup>1</sup>
	150-foot Right-of-Way/ Substation Disturbance Area	Improved Access Roads	New Access Roads		
Census Tract 402.02, Block Group 1	West Alternative, Central Alternative, Central Option 3 (N/C), Crossover Alternative	Central Option 3 (+)	West Alternative, Central Alternative, Central Option 3 (N/C), Crossover Alternative	No	No
Census Tract 402.02, Block Group 2	West Alternative	West Alternative	West Alternative	No	No
Census Tract 402.03, Block Group 3	West Alternative	West Alternative	West Alternative	No	No
Census Tract 404.03, Block Group 1	West Alternative	West Alternative	West Alternative	No	No
Census Tract 404.03, Block Group 2	West Alternative	--	West Alternative	No	No
Census Tract 404.04, Block Group 2	West Alternative	West Alternative	West Alternative	No	No
Census Tract 405.04, Block Group 1	Central Alternative, Central Option 3 (N/C), East Alternative, East Option 2 (N/C), Crossover Alternative	Central Alternative, Central Option 3 (N/C), East Alternative, East Option 2 (N/C), Crossover Alternative	Central Alternative, Central Option 3 (N/C), East Alternative, East Option 2 (N/C), Crossover Alternative	No	No
Census Tract 405.04, Block Group 2	Central Alternative, Central Option 3 (N/C), East Option 2 (+)	Central Alternative, Central Option 3 (N/C), East Option 2 (+)	Central Alternative, Central Option 3 (N/C), East Option 2 (+)	No	No
Census Tract 405.04, Block Group 3	Central Alternative, East Option 2 (+)	Central Alternative, East Option 2 (+)	Central Alternative, East Option 2 (+)	No	No
Census Tract 405.06, Block Group 1	West Option 3 (+), Central Alternative, East Alternative, East Option 2 (N/C), East Option 3 (N/C), Crossover Alternative	West Option 3 (+), Central Alternative, East Alternative, East Option 2 (N/C), East Option 3 (N/C), Crossover Alternative	Central Alternative, East Alternative, East Option 2 (N/C), East Option 3 (N/C), Crossover Alternative	No	No

**Table H-5. Minority and Low-Income Populations, by Action Alternative (continued)**

Geographic Area	Alternatives and Options			Minority Population <sup>1</sup>	Low-Income Population <sup>1</sup>
	150-foot Right-of-Way/ Substation Disturbance Area	Improved Access Roads	New Access Roads		
Census Tract 405.06, Block Group 2	West Option 2 (+), West Option 3 (+), Central Alternative, East Alternative, East Option 2 (N/C), East Option 3 (N/C), Crossover Alternative, Crossover Option 1 (N/C)	West Option 2 (+), West Option 3 (+), Central Alternative, East Alternative, East Option 2 (N/C), East Option 3 (N/C), Crossover Alternative, Crossover Option 1 (N/C)	West Option 2 (+), West Option 3 (+), Central Alternative, East Alternative, East Option 2 (N/C), East Option 3 (N/C), Crossover Alternative, Crossover Option 1 (N/C)	No	No
Census Tract 405.06, Block Group 3	West Alternative, West Option 2 (N/C), West Option 3 (N/C), Central Alternative, East Alternative, Crossover Alternative, Crossover Option 1 (N/C)	West Alternative, West Option 2 (N/C), West Option 3 (N/C), Central Alternative, East Alternative, Crossover Alternative, Crossover Option 1 (N/C)	West Alternative, West Option 2 (N/C), West Option 3 (N/C), Central Alternative, East Alternative, Crossover Alternative, Crossover Option 1 (N/C)	No	No
Census Tract 406.03, Block Group 4	West Option 2 (+), West Option 3 (+), Crossover Option 1 (+)	West Option 3 (+)	West Option 2 (+), West Option 3 (+), Crossover Option 1 (+)	No	No
Census Tract 406.04, Block Group 2	West Option 1 (N/C), West Alternative, West Option 2 (N/C), West Option 3 (N/C)	West Option 1 (N/C), West Alternative, West Option 2 (N/C), West Option 3 (N/C)	West Option 1 (N/C), West Alternative, West Option 2 (N/C), West Option 3 (N/C)	No	No
Census Tract 406.05, Block Group 1	West Alternative, West Option 2 (N/C), West Option 3 (N/C), Central Alternative, East Alternative, Crossover Alternative, Crossover Option 1 (N/C)	West Alternative, West Option 2 (N/C), West Option 3 (N/C), Central Alternative, East Alternative, Crossover Alternative, Crossover Option 1 (N/C)	West Alternative, West Option 2 (N/C), West Option 3 (N/C), Central Alternative, East Alternative, Crossover Alternative, Crossover Option 1 (N/C)	No	No

**Table H-5. Minority and Low-Income Populations, by Action Alternative (continued)**

Geographic Area	Alternatives and Options			Minority Population <sup>1</sup>	Low-Income Population <sup>1</sup>
	150-foot Right-of-Way/ Substation Disturbance Area	Improved Access Roads	New Access Roads		
Census Tract 406.05, Block Group 2	West Option 1 (N/C), West Alternative, West Option 2 (N/C), West Option 3 (-), Crossover Option 1 (+)	West Option 1 (N/C), West Alternative, West Option 2 (N/C), West Option 3 (-), Crossover Option 1 (+)	West Option 1 (N/C), West Alternative, West Option 2 (N/C), West Option 3 (-), Crossover Option 1 (+)	No	No
Census Tract 406.06, Block Group 1	West Option 1 (+)	West Option 1 (+)	West Option 1 (+)	No	No
Census Tract 407.03, Block Group 3	West Alternative	--	West Alternative	No	No
Census Tract 407.03, Block Group 4	West Alternative	--	West Alternative	No	No
Census Tract 407.06, Block Group 1	West Alternative	--	West Alternative	No	No
Census Tract 408.03, Block Group 2	West Alternative	--	West Alternative	No	No
Census Tract 408.03, Block Group 3	West Alternative	--	West Alternative	No	No
Census Tract 408.04, Block Group 2	West Alternative	West Alternative	West Alternative	No	No
Census Tract 408.05, Block Group 1	West Alternative	West Alternative	West Alternative	No	No
Census Tract 410.02, Block Group 1	West Alternative	West Alternative	West Alternative	No	Yes
Census Tract 410.02, Block Group 2	West Alternative	West Alternative	West Alternative	No	No
Census Tract 410.02, Block Group 3	West Alternative	West Alternative	West Alternative	No	No

**Table H-5. Minority and Low-Income Populations, by Action Alternative (continued)**

Geographic Area	Alternatives and Options			Minority Population <sup>1</sup>	Low-Income Population <sup>1</sup>
	150-foot Right-of-Way/ Substation Disturbance Area	Improved Access Roads	New Access Roads		
Census Tract 411.04, Block Group 1	West Alternative	West Alternative	West Alternative	No	No
Census Tract 411.04, Block Group 2	West Alternative	--	West Alternative	No	No
Census Tract 411.05, Block Group 1	West Alternative	--	West Alternative	No	No
Census Tract 411.05, Block Group 3	West Alternative	--	West Alternative	No	No
Census Tract 411.07, Block Group 1	West Alternative	--	West Alternative	No	No
Census Tract 413.12, Block Group 2	West Alternative	--	West Alternative	No	No
Census Tract 413.15, Block Group 1	West Alternative	West Alternative	West Alternative	No	No
Census Tract 413.15, Block Group 2	West Option 1 (N/C), West Alternative, West Option 2 (N/C), West Option 3 (N/C),	West Option 1 (N/C), West Alternative, West Option 2 (N/C), West Option 3 (N/C)	West Option 1 (N/C), West Alternative, West Option 2 (N/C), West Option 3 (N/C)	No	No
Census Tract 413.21, Block Group 2	West Option 1 (+)	--	West Option 1 (+)	No	No
Census Tract 414, Block Group 3	West Alternative, Central Alternative, East Alternative, Crossover Alternative	West Alternative, Central Alternative, East Alternative, Crossover Alternative	West Alternative, Central Alternative, East Alternative, Crossover Alternative	No	No

**Table H-5. Minority and Low-Income Populations, by Action Alternative (continued)**

Geographic Area	Alternatives and Options			Minority Population <sup>1</sup>	Low-Income Population <sup>1</sup>
	150-foot Right-of-Way/ Substation Disturbance Area	Improved Access Roads	New Access Roads		
Census Tract 415, Block Group 1	West Alternative, Central Alternative, East Alternative, Crossover Alternative	West Alternative, Central Alternative, East Alternative, Crossover Alternative	West Alternative, Central Alternative, East Alternative, Crossover Alternative	No	No
Census Tract 415, Block Group 2	West Alternative, Central Alternative, East Alternative, Crossover Alternative	--	West Alternative, Central Alternative, East Alternative, Crossover Alternative	No	No
<b>Oregon</b>	--	--	--	<b>No</b>	<b>No</b>
<b>Multnomah County</b>	--	--	--	<b>No</b>	<b>No</b>
Census Tract 102, Block Group 1	West Alternative, Central Alternative, East Alternative, Crossover Alternative	--	West Alternative, Central Alternative, East Alternative, Crossover Alternative	No	No

**Notes:**  
 N/C – No change from the action alternative.  
 (+) – this block group is crossed by the option but not the alternative.  
 (-) – this block group is crossed by the alternative but not the option.  
 1. The minority and low-income population data and analysis are in Tables 2-2 and 2-3.

Sources: U.S. Census Block Groups Boundary (Environmental Systems Research Institute, Inc. (ESRI); U.S. Census Bureau 2000: Census 2000 Summary File 3, Detailed Table P87, Accessed January 19, 2011, Available online at <http://factfinder.census.gov/>; U.S. Census Bureau 2000, Census 2000 Summary File 3, Detailed Table P53, Accessed January 19, 2011, Available online at <http://factfinder.census.gov/>;

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## **Appendix I**

### **Cultural Resources Sensitivity Scores**



# Appendix I Cultural Resources Sensitivity Scores

There are four factors that influence the locations of cultural resources likely to be present in various segments of the BPA I-5 Corridor Reinforcement Project. These four factors are environmental, archaeological, ethnographic, and historic. Archaeological Investigations Northwest's (AINW) methods for assessing these four factors to determine the mean cultural sensitivity score of each segment and design option are described below. These data were then used to identify proposed transmission tower locations at known locations of cultural resources and to determine which of the four proposed route alternatives and associated design options is the least culturally sensitive.

The environmental data assessment is based on the Washington Statewide Predictive Model (prepared by the Washington State Department of Archaeology and Historic Preservation [DAHP]) and information about potential buried land surfaces. For each segment within the project, eight environmental variables were examined in order to determine the relative potential of each segment for containing pre-contact archaeological sites. These environmental variables were considered in reference to their spatial distribution within each of the project segments, and were calculated as a percentage of the total area (in acres) of each segment. The methods of assessing these environmental data and the rationale for scoring these variables are described in detail below. In short, because the cultural sensitivity score for environmental data is based on the percentage of geographical area within each segment, the score is on a scale of 0 to 100. More detailed information on environment assessment scoring is presented in the following section.

Known archaeological, ethnographic, and historic resources were tabulated for each segment of the project. "Predictors" for additional archaeological and historic resources were also tabulated for each segment based on the results of historic research. "Red flags" include areas of spiritual importance to the Cowlitz Tribe as well as locations where human burials are known to be present. The methods of collecting and assessing these data are described below. Within the three disciplines (archaeology, ethnography, and history), the known resources and predictors were assigned numeric values, as described below for each discipline. Red flags were tabulated by project segment, but were not assigned numeric values. The numeric values for resources and predictors were added together to provide a "raw score" for each segment, and red flags that may be present were also noted.

The raw scores were then normalized within each of these three disciplines on a 100-point scale to produce a cultural sensitivity score for each segment for each discipline. Normalization was achieved by taking the segment with the highest raw score within each discipline and dividing 100 by that score to obtain a normalizing factor for that discipline. For example, Segment 52 has the highest raw score for archaeology of any segment with a value of 31. Dividing 31 into 100 yields a normalizing factor of 3.22. The raw score for archaeology for each segment was then multiplied by 3.22 to provide a normalized cultural sensitivity score. The normalizing factors for ethnography and history were calculated in the same way; the normalizing factor for ethnography is 5.00, and the normalizing factor for historic resources is 1.23. Normalizing the scores on a 100-point scale allows for direct comparisons between the environmental (already calculated on a 100-point scale), archaeological, ethnographic, and historic cultural sensitivity scores for each project segment.

The mean cultural sensitivity score for each segment was calculated by adding the environmental, archaeological, ethnographic, and historic cultural sensitivity scores and dividing by 4. Thus, in calculating the mean cultural sensitivity score, the four disciplines are weighted evenly. Proposed transmission tower locations at known cultural resources were also identified by AINW. These potential impacts were not assessed a numeric value or incorporated into the overall cultural sensitivity score of each segment. Once the assessment of individual segments and proposed tower locations was completed, AINW used the resulting data to assess the four action alternatives and their associated design options to determine which action alternative was the least culturally sensitive, potentially presenting BPA with fewer cultural resource issues.

## **Appendix K**

### **Fish Habitat and Fish Population Impacts**



**ASSESSMENT OF RELATIVE FISH HABITAT AND FISH POPULATION IMPACTS OF  
I-5 CORRIDOR REINFORCEMENT PROJECT ALTERNATIVES AND OPTIONS**

*Report to:*

Bonneville Power Administration  
Portland Oregon

*Report by:*

Gardner Johnston & Josh Epstein,  
*Inter-Fluve, Inc.*  
*Hood River, Oregon*

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July 5, 2012

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## SUMMARY

Bonneville Power Administration (BPA) is proposing to construct a new 500-kV transmission line in a north/south alignment over approximately 70 miles between a new substation near Castle Rock, Washington and a new substation near BPA's existing Troutdale Substation in Multnomah County, Oregon. This assessment estimates the relative potential of route alternatives and options for impact on fish and fish habitat. This information will be used to prepare a National Environmental Policy Act Draft Environmental Impact Statement for the project.

Effects of transmission line and access construction and operation on fish resources will be a function of the number and types of project activities, the intensity of disturbance, the nature of the associated habitat impacts, and the response of fish species and populations to habitat alteration. Indices used in this assessment are based on indicators of: 1) project impacts on hydrology, sediment, riparian, and floodplain characteristics known to be strongly related to the productivity of fish habitat, and 2) changes in fish production occurring as a consequence of habitat alteration. This assessment does not provide absolute estimates of project impacts on fish resources, but the indices used in the assessment do provide a basis for evaluating the magnitude of project impact at multiple scales. For the purposes of this analysis, all project effects on fish resources are assumed to be indirect via their influence on fish habitat (see Figure 1). Index values and rankings are summarized in Table 1 and Table 2, respectively. Brief summaries follow.

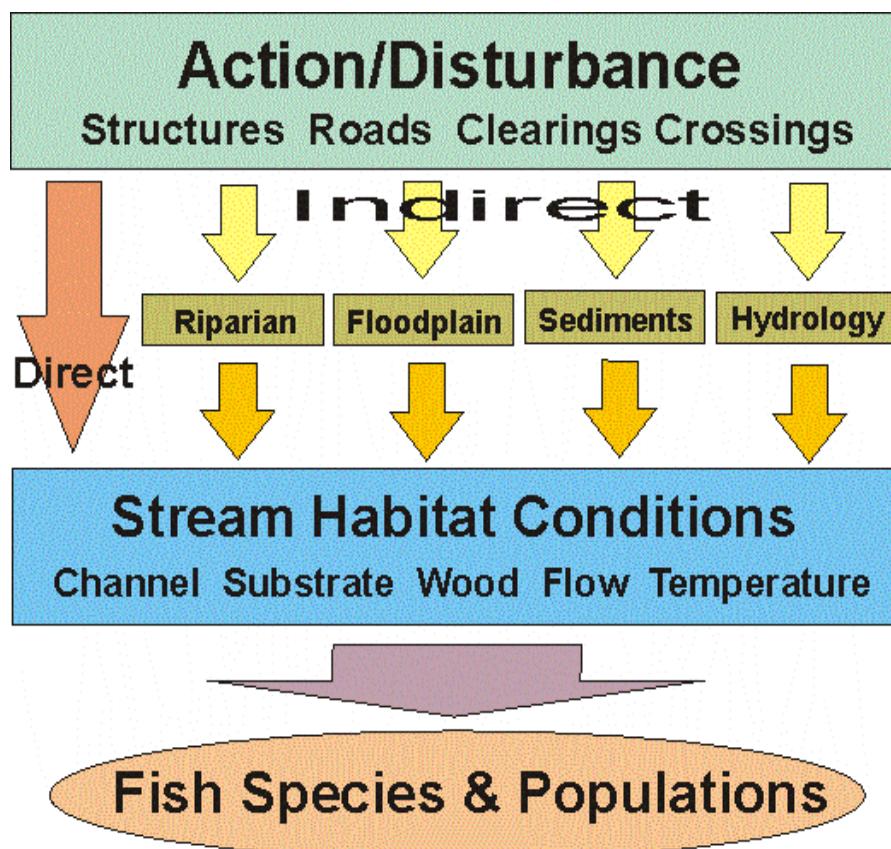


Figure 1. Conceptual description of habitat-mediated project effects on fish resources.

**Table 1. Summary of fish habitat and fish impact index values (sorted by increasing impact based on the Integrated Fish Impact index).**

Alternative	Hydrology	Sediment	Riparian		Floodplain	Fish Impact
			Near-term	Long-term		
West Option 2	127	303	5,592	9,024	15.3	0.08
West Option 3	141	295	6,153	9,750	15.6	0.09
East Option 3	962	106	9,340	10,287	10.2	0.09
East Option 2	875	94	10,312	11,546	10.4	0.09
West Option 1	111	368	5,926	9,112	21.9	0.11
West Alternative	118	361	6,054	9,239	18	0.11
Central Option 3	652	97	11,141	12,363	9.5	0.11
Central Option 2	687	114	10,550	12,575	7.7	0.14
Central Alternative	725	119	12,006	14,207	9.2	0.15
Central Option 1	744	119	12,373	14,797	9.2	0.15
East Option 1	921	105	7,483	8,559	9.1	0.19
East Alternative	929	106	9,344	10,252	10.9	0.19
Crossover Alternative	512	132	9,291	11,319	9	0.20
Crossover Option 2	523	146	9,385	11,413	9.4	0.21
Crossover Option 3	458	145	9,588	12,174	9.5	0.21
Crossover Option 1	515	146	10,027	12,200	10.7	0.24

**Table 2. Summary of fish habitat and fish impact index ranks (sorted by increasing impact based on the Integrated Fish Impact index; 1-highest impact; 16-lowest impact).**

Alternative	Hydrology	Sediment	Riparian		Floodplain	Fish Impact
			Near-term	Long-term		
West Option 2	14	3	16	15	4	16
West Option 3	13	4	13	12	3	14
East Option 3	1	12	10	10	8	15
East Option 2	4	16	5	7	7	13
West Option 1	16	1	15	14	1	11
West Alternative	15	2	14	13	2	12
Central Option 3	8	15	3	4	10	10
Central Option 2	7	11	4	3	16	9
Central Alternative	6	9	2	2	13	8
Central Option 1	5	10	1	1	12	7
East Option 1	3	14	12	16	14	6
East Alternative	2	13	9	11	5	5
Crossover Alternative	11	8	11	9	15	4
Crossover Option 2	9	5	8	8	11	3
Crossover Option 3	12	7	7	6	9	2
Crossover Option 1	10	6	6	5	6	1

## Hydrology

The Stream Hydrology Impact Assessment evaluates the potential effects of alternative transmission line routes and new access roads on increased runoff and peak flows. This assessment used the Washington Forest Practice Board Manual (2011) method for hydrologic condition, which uses satellite imagery to quantify hydrologic maturity (the ability of vegetation to mitigate snow accumulation and snow melt). A single index was developed to gauge indirect effects. Index values reflect potential changes in the area of hydrologically immature cover within each subwatershed crossed by the alternatives and alternative options. Increases in hydrologically immature land cover can lead to increased runoff and peak flows.

The increase in hydrologically immature land cover as a consequence of transmission line corridors and new access roads would be low (less than about 1,000 acres) for all alternatives and alternative options. Consequently, the increase in runoff and peak flows would be low, at levels that would have no adverse impacts to stream channel habitat and fish resources. Potential impacts would generally be lowest for the West Alternative and options and greatest for the East Alternative and options. Rankings are best explained by the amount of hydrologically immature land cover already present. The West Alternative and options would cross subwatersheds that have higher urban development, greater agricultural land use, and greater hardwood cover—all already hydrologically immature. Proceeding east, there is less development, less agriculture, and higher conifer cover—clearing would convert more area to hydrologically immature land cover. However, in all instances, the percent change would be slight (<1%). Given the limited change, this indirect effect was not carried forward to the Fish Impact Assessment.

## Sediment

The Sediment Impact Assessment evaluates the potential effects of construction of unsurfaced access roads and transmission line corridors on increased sediment delivery. This assessment used the Integrated Watershed Assessment method (LCFRB 2010a) for determining potential fine sediment delivery in subwatersheds crossed by the action alternatives. The potential effect of alternatives and alternative options on watershed-scale sediment delivery to stream channels was estimated as a function of: 1) the natural erodibility within a subwatershed, 2) the extent of the existing road network (aka “the managed condition”), 3) the effect of new roads on sediment generation and delivery, and 4) the effect of the transmission line corridors on sediment generation and delivery.

The increase in potential fine sediment delivery as a consequence of transmission line corridors and new access roads would be low for all alternatives and alternative options. Potential impacts would generally be greatest for the west alternative and options which would cross more erodible terrain, while the other alternatives and options would cross less erodible underlying geology. Even though the West Alternative and options would have the least unsurfaced road construction, they would have the greatest increase in sediment delivery because these roads would be constructed on an erodible geology. The results appear to show that alternatives requiring the construction of access roads in more erodible terrain would result in higher sediment impacts. The highest index values are found in the West Alternative and options, while the East and Central alternatives and options were found to have the lowest

index values. However, in all instances, the percent change would be slight (<1%). Given the limited change, this indirect effect was not carried forward to the Fish Impact Assessment.

### Riparian

The Riparian Impact Assessment evaluates the potential effects of alternative transmission line corridors on loss of riparian function along fish-bearing streams. This assessment used the Washington Forest Practice Board Manual (2011) method for assessing riparian function, which uses aerial photo interpretation to quantify two specific processes: 1) the recruitment of large woody debris, and 2) the provision of stream shade. Near-term and long-term indices integrate these assessments to gauge direct and indirect impacts. Index values reflect the length of stream cleared by alternatives and alternative options, weighted by the riparian function provided by the vegetation lost through clearing.

This loss of riparian vegetation as a consequence of transmission line clearing could have a measurable impact on fish populations. Near-term, it would be equivalent to the loss of about 1 to 2.5 miles of highly-functioning riparian vegetation. Long-term, the loss would be slightly greater. Near-term, the West Alternative and options would have the least riparian function loss while the Central Alternative and options would have the greatest. The West Alternative and options have discernibly greater levels of degradation and encroachment of non-forest land uses leading to lower riparian function ratings. Long-term, the ranking is correlated with length of stream cleared of forested vegetation. As riparian vegetation grows and reaches potential riparian function, differences in riparian function would decrease. East option 1 would have the least amount of stream length cleared. Otherwise, long-term rankings are more or less similar to near-term rankings. Given the magnitude of potential riparian function loss that could occur, this indirect effect was carried forward to the Fish Impact Assessment.

### Floodplain

The Floodplain Impact Assessment evaluates the potential effects of alternative transmission line corridors, access roads, and transmission towers on loss of floodplain function along fish-bearing streams. This approach quantified the effect of alternatives and options on floodplains by integrating the following: 1) the amount of reduction in forest vegetation within floodplains, 2) the number and footprint area of new towers that would be constructed within the floodplain, and 3) the length and area of new or reconstructed roads within the floodplain. Index values reflect the total floodplain area affected.

The total floodplain area impacted would range from 7.7 to 21.9 acres as a consequence of transmission line clearing, new or improved access roads, and new towers. The West Alternative and options would have the greatest total impact area because they cross broad floodplain areas within the lower portion of large rivers. The East Alternative and options would generally have the second greatest impact. The Crossover and Central alternatives and options would generally have the least amount of impact. Given the total area of impact and due to the presence of existing floodplain impairments, the overall impact on floodplain processes, including floodplain inundation and long-term channel adjustment, is expected to be relatively minor. This effect was not carried forward to the Fish Impact Assessment.

## Fish Impact

The Fish Impact Assessment uses production value of listed salmon and steelhead in streams as an index of the relative potential or risk of impact of alternative corridor routes on fish resources. While a variety of fish species occur in the region, listed salmon and steelhead are of particular concern and will be the focus of biological assessments required by their listing status. Fish impact potential is related to: 1) the fish production value in the stream reach affected by the project and 2) the extent to which reductions in fish production may be realized as a result of direct and indirect project-related impacts on fish habitat or fish habitat forming processes.

Fish production potential is expressed in terms of fish numbers (adult salmon), percentage of the population, and percentage of populations identified as a priority for salmon protection and restoration in Salmon Recovery Plans adopted by the State of Washington Department of Fish and Wildlife (WDFW) and the National Marine Fisheries Service (NMFS). Fish numbers are estimated within the footprint of the right-of-way at each stream crossing for each of the four listed salmon and steelhead species. Stream crossings are a convenient way to represent all project activities that might directly or indirectly affect fish habitat.

An Integrated Fish Impacts index describes the amount of fish potential that might be expected to be affected by fish habitat changes based on findings of the hydrology, sediment, riparian, and floodplain impact analyses in order to rate the loss of fish productivity associated with potential habitat impacts. The Integrated Fish Impacts index estimates the proportional reduction in fish numbers associated with project-related habitat degradation at the crossing scale. Units of this index are expressed as the average percentage of high priority populations for all listed salmon and steelhead species potentially affected by the alternatives and alternative options.

The proportional reduction in fish numbers associated with project-related habitat degradation would be quite low for all alternatives and options. The Integrated Fish Impacts index value would be 0.3% or less for all species and for most options. Population-level Integrated Fish Impacts index values up to 0.95% were estimated for winter steelhead due to several crossings occurring in relatively high-value streams for steelhead with highly-functioning riparian vegetation that will require clearing. Overall, the magnitude of reduction in fish production indicated by this index would not affect population recovery of these federally-listed species.

West Alternative and options rank among the lowest fish impacts based on the Integrated Fish Impacts index. Fish production potential is generally higher because routes included a higher number of crossings and many of these occurred at relatively high-value streams for anadromous species. However, project related habitat effects would be relatively low in comparison with other routes because many stream crossing would occur at locations where conditions in the right of way are already altered. Hence, these routes would generally require much less clearing of highly-functioning riparian vegetation. Differences among the alternatives and options were driven by variations in the Washougal basin east of Vancouver.

Crossover Alternative and options are generally ranked with highest impacts due to both higher fish production potential and more clearing of highly-functioning riparian vegetation. These routes would cross a greater number of anadromous fish-bearing streams, including many low

to intermediate elevation streams which produce more fish and more species of fish on a per unit-length basis. Affected populations are more frequently identified in the salmon recovery plan as high priorities for habitat protection or restoration. More riparian zones in these areas would require clearing and riparian zones are more likely to be highly functional. Hence, reductions in fish production potential would likely be greater.

*Central Alternative and options* are generally ranked intermediate between East and Crossover alternatives and options in terms of fish impact based on the Integrated Fish Impacts index. The number of crossings of anadromous fish-bearing streams would be intermediate. Fish production potential is also intermediate at these crossings. The magnitude of riparian clearing and functional rating of riparian zones would be intermediate as well.

*East Alternative and options* rank from low to moderately high based on the Integrated Fish Impacts index. Fish production potential is relatively low because the number of crossings of anadromous fish-bearing streams would be lower than other alternatives and these routes would generally cross smaller, higher elevation streams that are inhabited at relatively low densities by a limited number of species (typically steelhead and coho). However, many of these crossing would require substantial clearing of relatively high-functioning riparian vegetation.

## INTRODUCTION

Bonneville Power Administration is proposing to construct a new 500-kV transmission line in a north/south alignment over approximately 70 miles between a new substation near Castle Rock, Washington and a new substation near BPA's existing Troutdale Substation in Multnomah County, Oregon. The transmission line towers would carry conductors for the electricity, overhead ground wires for lightning protection, and fiber optic lines for communication needs. BPA would construct new and improve existing access roads to each tower site in order to accommodate construction and maintenance of the new transmission line.

Four route alternatives have been identified (Figure 2). Each alternative also includes options. Alternatives and alternative options consist of segments, some of which are sited parallel to existing transmission lines, either within or adjacent to the existing right-of way, and some are located in new right-of-way. This assessment evaluates alternatives and options based on their relative impacts to fish resources, including salmon and steelhead species listed under the U.S. Endangered Species Act (ESA). This information will be used to prepare a National Environmental Policy Act (NEPA) Draft Environmental Impact Statement (DEIS) for the project.

A variety of fish species occur in streams potentially affected by the project. Of particular concern are four listed salmon and steelhead species (including a total of six races):

- Lower Columbia River coho salmon (*Oncorhynchus kisutch*)
- Lower Columbia River Chinook salmon (*Oncorhynchus tshawytscha*) – spring and fall races
- Columbia River chum salmon (*Oncorhynchus keta*)
- Lower Columbia River steelhead (*Oncorhynchus mykiss*) – summer and winter races

Two other federally-listed species also occur in southwest Washington streams but are not likely to be affected by the project. Distribution of the threatened bull trout (*Salvelinus confluentus*) is mostly found in areas outside of the project influence. Eulachon (Columbia River Smelt, *Thaleichthys pacificus*) occur in the lower portions of major Columbia River tributaries where the scale of project impacts is expected to be minimal. Other noteworthy species with a wide distribution in the region include the resident coastal cutthroat trout (*Oncorhynchus clarkii clarkii*), and the anadromous Pacific lamprey (*Lampetra tridentata*).

Effects of transmission line and access construction and operation on fish resources will be a function of the number and types of project activities, the intensity and persistence of project disturbance, the nature of the associated habitat impacts, and the response of each fish species to habitat alteration. Fish species will be affected by the direct and indirect effects of project actions on fish habitat (see Figure 1). Direct effects on fish habitat might include stream channel alterations or migration blockages due to construction of structures or access roads within or across streams. Indirect effects on fish habitat might result from project alteration of watershed conditions affecting hydrology and sediment delivery or crossing-scale changes in riparian and floodplain function. Watershed and crossing-scale effects can impact fish production via changes to fish habitat that decrease fish carrying capacity and/or survival.

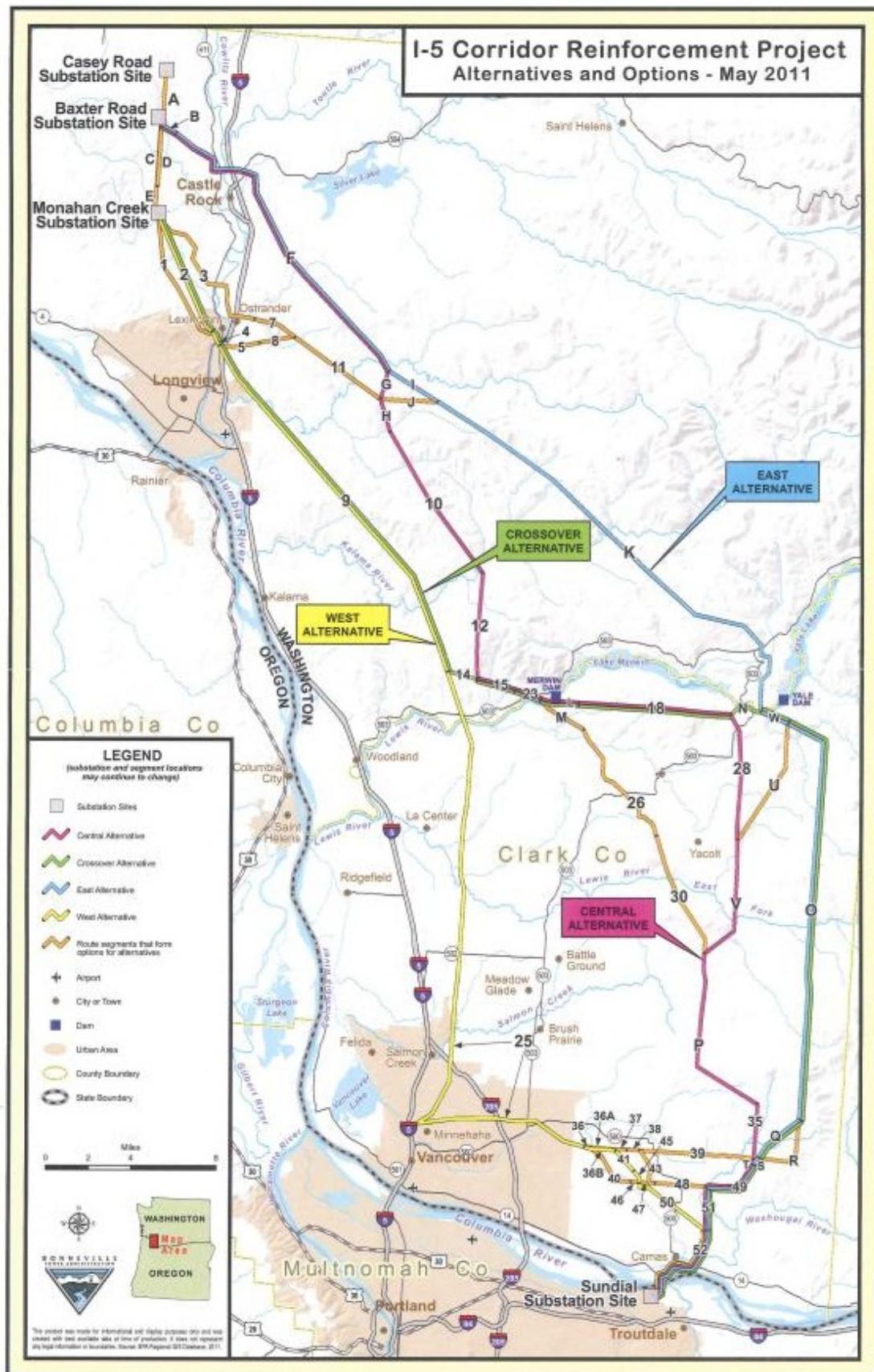


Figure 2. I-5 Corridor Reinforcement Project alternatives and options (May 2011).

This assessment uses *indices* of the project impacts on fish habitat and fish numbers that can be quantified with relatively high confidence. Indices used in this assessment are based on indicators of: 1) project impacts on hydrology, sediment, riparian, and floodplain known to be strongly related to the productivity of fish habitat, and 2) changes in fish production occurring as a consequence of habitat alteration. These indices provide a basis for comparison of the relative impact of project routes and alternatives on fish resources, and they are most useful for ranking routes and alternatives to inform selection of a preferred route through the DEIS. These indices also provide some basis for evaluating the magnitude of project impacts at a project scale. In addition, these indices will be useful for characterizing the causal mechanisms and spatial distribution of project impacts which will provide guidance for mitigation measures.

## **STREAM HYDROLOGY IMPACT ASSESSMENT**

The Stream Hydrology Impact Assessment evaluates the potential effects of alternative transmission line corridors and new access roads on increased runoff and peak flows. Any given subwatershed might support none, some, or all of four listed salmon and steelhead species.

This assessment used the Washington Forest Practice Board (WaFPB) Manual (2011a) method for hydrologic condition of subwatersheds crossed by the action alternatives. These procedures integrate general watershed characteristics that are likely to significantly affect storm runoff, including land use patterns, structural features, disturbance history, and climate. This assessment focuses on land use patterns as they influence hydrologic maturity. Hydrologic maturity was interpreted from recent Landsat imagery within each subwatershed. Using this protocol provides a systematic means of characterizing hydrologic condition.

Using these interpretations, a single index value was developed to reflect the potential impacts of alternative transmission line corridors on increased runoff and on peak flows in affected subwatersheds. Index values were based on the potential impact of the vegetation clearing on the area of hydrologically immature land cover. Index values reflect potential impacts from transmission line corridors and new access roads. The index values capture a number of important considerations when analyzing impacts, including the area of vegetation cleared in construction and maintenance of transmission line corridors and new access roads and the dominant vegetation types and total crown closure of cleared areas.

### ***Background***

The hardened surfaces of new roadbeds and areas disturbed by new road construction could increase surface runoff and peak flows in streams (Grant et al. 2008). An increase in peak flows associated with transmission line clearing could occur through vegetation removal of hydrologically mature vegetation along the right-of-way. Continued maintenance of hydrologically immature cover along the right-of-way would occur. Opening of the canopy can cause greater snow accumulation, increased snowmelt in spring, accelerated melt rates, reduced rates of interception and evapotranspiration, and augmentation of storm runoff volume due to increased soil moisture or snowmelt (Harr 1981, Ziemer and Lisle 1998). The greatest potential for adverse change from increased runoff and peak flows in streams exists in watersheds within rain-on-snow and snow-dominated precipitation zones (Harr 1981).

Excessive peak flows can scour streambeds and in some instances can cause debris torrents that alter stream channels (Grant et al. 2008). Flooding and debris torrents in fish-bearing streams can degrade fish habitats by destroying egg pockets and rearing areas, altering pool and riffle sequences, and removing large woody debris (Booth 1990, Grant et al. 2008). Excessive peak flows can also expedite the flushing of available nutrients from streams (Lamberti et al. 1989). Water that runs off into streams is not available for recharging ground water sources which contribute to summer flows. Increased peak flows can result in simplified habitats, reduced nutrients, and unsuitable summer conditions, which decrease fish growth and survival (Bjornn and Reiser 1991, Spence et al. 1996). This assessment focuses on changes in vegetation conditions that could lead to these impacts. We address the potential magnitude of impacts to aquatic habitat via excessive peak flows in the Discussion.

## **Methods**

### Data

Locations of subwatersheds were obtained from the Washington Lower Columbia Fish Recovery Board (LCFRB) that was compiled as part of Recovery Plan development. All subwatersheds containing transmission line corridors or new access roads were assessed. A 150-foot buffer width was used to establish the transmission line corridor footprint. A 30-foot buffer width was used for new access roads. Only new access roads outside of the transmission corridor were assessed. Clearing due to new access roads inside the transmission line corridor are already covered by the transmission line corridor area.

Interpretation of hydrologic maturity was conducted using LANDFIRE data sets. LANDFIRE (also known as Landscape Fire and Resource Management Planning Tools) is an interagency vegetation, fire, and fuel characteristics mapping program, sponsored by the United States Department of the Interior and the United States Department of Agriculture (USDA), Forest Service. We used the Existing Vegetation Type (EVT) layer, which represents the species composition currently present at a given site, and the Existing Vegetation Cover (EVC) layer, which represents the vertically-projected percent cover of the live canopy layer. These layers are processed at a 30-meter cell resolution. We used the 2008 refresh, which is based on 2001 LANDSAT imagery but incorporates vegetation changes and disturbances through 2008.

### Index

The Hydrologic Change index quantifies the potential change in the area of hydrologically immature land cover. This index is calculated at an adequate resolution to detect even minor changes. Hydrologically immature forested land cover is defined in the WaFPB Manual (2011a) method for hydrologic change as forested areas with less than 10% total crown closure and/or more than 75% of the tree crown in hardwoods. Non-forested land cover is also considered hydrologically immature. Attributes in the LANDFIRE data sets were used to apply these rules to determine area, pre- and post-project, in this condition. The correlation between LANDFIRE attributes and land cover is provided in Appendix A.

## **Results**

Appendix A lists 87 subwatersheds crossed by all alternatives and options. For each subwatershed, the following information is provided by alternative and option:

- Is the subwatershed crossed by transmission line corridors or new access roads?
- Pre-project area (acres) of hydrologically immature land cover in the subwatershed
- Post-project area (acres) of hydrologically immature land cover in the subwatershed

Table 3 summarizes the Hydrologic Change index for each alternative and alternative option. It also summarizes the total area in subwatersheds crossed by the alternatives and options, the area in these subwatersheds with hydrologically immature land cover, the change (increase) in hydrologically immature conditions due to transmission line corridors and new access roads (outside of the transmission line corridors), and the index value. Alternatives and options are sorted from the lowest index value to the greatest, reflecting increasing impacts.

**Table 3.** Hydrologic Change index values for action alternatives and options. Values are sorted by increasing index score, from least hydrologic change to most.

Alternative	Total Subwatershed Area (ac)	Hydrologically Immature Area (ac)					Percent Change
		Pre-Project	Change-Trans. Line Corridors	New Access Roads	Hydrologic Change Index		
West Option 1	164,857	130,988	104	7	111	0.08%	
West Alternative	161,133	127,612	111	7	118	0.09%	
West Option 2	167,652	132,819	120	7	127	0.10%	
West Option 3	180,528	143,156	132	10	141	0.10%	
Crossover Option 3	195,587	114,316	422	36	458	0.40%	
Crossover Alternative	184,405	108,041	477	35	512	0.47%	
Crossover Option 1	184,405	108,041	479	35	515	0.48%	
Crossover Option 2	195,587	114,316	487	36	523	0.46%	
Central Option 3	207,371	119,872	605	47	652	0.54%	
Central Option 2	208,504	119,032	633	54	687	0.58%	
Central Alternative	217,922	121,872	676	49	725	0.59%	
Central Option 1	224,210	124,932	694	50	744	0.60%	
East Option 2	234,082	112,521	834	41	875	0.78%	
East Option 1	211,468	94,457	867	53	921	0.97%	
East Alternative	209,261	91,312	878	51	929	1.02%	
East Option 3	209,261	91,312	897	64	962	1.05%	

Hydrologic Change index values are substantially different at the extremes and exhibit a more or less uniform rate of decrease from the lowest to highest score. Despite these trends, the relative change in hydrologically immature conditions would be limited. Along the East Alternative and options, percent change from pre-project conditions would be about 0.78% to 1.05%. This decreases to about 0.6% for the Central Alternative and options; about 0.5% for the Crossover Alternative and options; and, only about 0.1% for the West Alternative and options. Overall, index values are generally lowest for the West Alternative and options and greatest for the East Alternative and options. The Central and Crossover alternatives and options are in the middle of the overall rankings.

### ***Discussion***

By using consistent assessment procedures informed by consistent data sources, results are comparable among alternatives and options. This assessment was a desktop exercise and more accurate determinations can be made through aerial photo interpretation. Specifically, better information could be obtained about the location of recent disturbances (e.g., urban development, land clearing, regeneration timber harvests) not represented by the LANDFIRE data. Any of these could improve determination of hydrologic immaturity, but this uncertainty affected all alternatives and options more or less equally. Therefore, the relative ranking of alternatives and alternative options is reliable for planning purposes.

The strongest predictor of increase in hydrologically immature land cover is the proportion of hydrologically immature land cover in subwatersheds crossed. It is inversely related to the index values. That is, as the proportion of hydrologically immature land cover increases there is less change in hydrologic conditions. There are two ways to interpret this. One way is that when there is more hydrologically immature land cover, odds are greater that it will be used by a transmission line—thus avoiding conversion of otherwise hydrologically mature land cover. The other way is that when there is more hydrologically mature land cover, odds are greater that it will be cleared, creating hydrologically immature conditions. Both appear to be at play.

The lowest change would occur along the West Alternative and options. Almost 80% of the land cover in subwatersheds which would be crossed by the West Alternative and options is hydrologically immature. There is higher urban development, greater agricultural land cover, and greater hardwood cover. There would also be greater use of existing transmission line clearings. Collectively, this would increase the amount of hydrologically immature land cover used and decrease the amount of mature land cover cleared. In comparison, about 40% to 50% of the land cover in subwatersheds which would be crossed by the East Alternative and options is hydrologically immature. There is less development, less agriculture, and more conifer cover. Forest management creates immature conditions, but only briefly. These factors appear to directly affect ranking of alternatives and alternative options.

A full hydrologic change analysis following the WaFPB Manual (2011a) integrates this information with physiographic and climatic characteristics to estimate the effect on water available for runoff (WAR)—the rain-plus-snowmelt input—and ultimately peak flow. Generally, water availability increases as snow accumulation and storm precipitation increase, but snowmelt can be moderated as storm temperatures and wind speeds decrease. According to the models, snow accumulation increases as elevation increases; however, elevation increases will moderate snowmelt via decreased storm temperatures. In the subwatersheds crossed by the action alternative, storm precipitation is directly related to elevation (WaDOT 2006). Land cover influences snow accumulation and snowmelt; hydrologically immature conditions will increase both by increasing snow-water equivalence and wind speeds, respectively.

These relationships provide a basis for assessing the utility of the Hydrologic Change index for assessing the potential effects of alternative transmission line routes and new access roads on increased runoff and peak flows. Preliminary model calculations indicate that 24-hour snowmelt does not exceed snow accumulation in these subwatersheds. Therefore, WAR is determined by storm precipitation and snowmelt; both of which are influenced by elevation. Snowmelt is also influenced by hydrologically immature land cover; this influence is moderated slightly with increased elevation. The overall implication of this is that the Hydrologic Change index is a fairly consistent measure of increased runoff across subwatersheds. The relative influence of increased runoff on peak flows varies, however, with flow and precipitation. But, given the low increase in hydrologically immature conditions, peak flow increases are likely low (<10%), as well. Peak flow increases less than 10% are assumed to have no adverse effects (WaFPB 2011a). Long-term changes in watershed conditions would therefore be minor; however, local impacts could occur that result in locally high impairment to hydrology functions.

## **SEDIMENT IMPACT ASSESSMENT**

The Sediment Impact Assessment evaluates the potential effects of alternative transmission line routes and new access roads on instream sediment and turbidity. Any given subwatershed might support none, some, or all of four listed salmon and steelhead species.

This assessment used the Integrated Watershed Assessment (IWA) analysis method (LCFRB 2010a) for determining potential fine sediment impairment of subwatersheds crossed by the action alternatives. These procedures integrate general watershed characteristics that are likely to significantly affect sediment delivery, including geology and land surface slope. We focused on patterns as they influence natural sediment delivery of the subwatershed, and sediment delivery from managed land use. Using this protocol provides a systematic means of characterizing potential sediment impacts.

Using these interpretations, a single index value was developed to reflect the potential impacts of alternative transmission corridor segments and access roads on increased sediment delivery in affected subwatersheds. Index values were based on the potential impact of the vegetation clearing and road construction and how those impacts affect erosion and sediment delivery. Index values reflect potential impacts to sediment delivery within each subwatershed crossed by transmission line corridors or new access roads.

### ***Background***

The project has the potential to influence sediment delivery to stream channels through the construction of unsurfaced access roads and through the construction of transmission line corridors. Road construction activities such as cutting and backfilling could expose topsoil or loose sediment. Newly constructed roadbeds and surfaces would be a mix of coarse and fine material. Traffic during construction and operation and maintenance has the potential to expose and loosen sediment. During rain events, fine sediments can be eroded from the road surface and delivered to ditches and ultimately to streams (Ziemer and Lisle 1998). Sediment production from roads would vary depending on design, surfacing, sediment controls, and traffic (Furniss et al. 1991). Increased sediment production from rain events and from traffic could increase sediment loading in streams (Luce and Black 2001).

Construction of transmission line corridors could expose topsoil or loose sediment in right-of-way clearings. Sediment could be eroded and delivered to streams during rain events. Clearing of riparian vegetation in transmission line corridors also increases the potential for hillside erosion as well as stream bank erosion and direct delivery of sediments to streams. Loss of vegetation along streams also decreases the buffering capacity of the riparian vegetation. Periodic vegetation removal during maintenance could result in long-term reduced buffering capacity of the riparian vegetation, increased potential for hillside erosion, and increased potential for stream bank erosion (Chamberlin et al. 1991).

Increased sediment loading in fish-bearing streams can alter habitats and reduce the growth and survival of fish (Anderson et al. 1996, Suttle et al. 2004). For many fish species, eggs are deposited among gravels on the stream bottom. When these gravels become clogged with sediments, the free flow of oxygenated water and removal of wastes is impaired, resulting in egg suffocation and mortality (Anderson et al. 1996). Suspended sediments can clog and abrade

fish gills, affecting behavior or causing suffocation (Newcombe and Jensen 1996), and can also reduce water clarity, making it difficult for some fish to find food or detect predators (Sigler et al. 1984). Turbid water can cause a stress response in salmon (Redding et al. 1987), which may result in reduced growth and reduced ability to tolerate additional stressors. Turbid water can also alter outmigration behavior, impair immune system function, and degrade osmoregulation capabilities (Newcombe and Jensen 1996).

### **Methods**

This assessment used the IWA natural erodibility rating (from LCFRB 2010a) and the existing unsurfaced road density to determine a Sediment Delivery index. The Sediment Delivery index for the “pre-project” condition is compared to a “post-project” Sediment Delivery index, which incorporates the change in unsurfaced road density and transmission line corridors. The analysis was performed at the “litho-subwatershed” spatial scale. This represents an area with the same underlying lithology within a subwatershed (Figure 3). The subwatersheds were determined using the LCFRB Subwatershed Dataset, and the underlying lithology was determined using the Washington Department of Natural Resources (WaDNR) 1:100,000 scale 2010 Geology dataset. Road densities were calculated using WaDNR 2012 transportation infrastructure data for Cowlitz and Clark counties.

#### Determining the Natural Erodibility Rating (N)

The natural erodibility rating characterizes a natural or background condition by integrating geology type and the underlying land surface slope. Higher N values are assigned to areas with highly erodible geology and steeper slopes, while the lowest values are found in areas with geology that is relatively hard to erode and with gentle land surface slopes. The land surface slope was calculated from the National Elevation Dataset 10-meter DEM.

The pre-project condition is represented by the index based on methods developed for the IWA analysis (LCFRB 2010a). This index takes into account the underlying geology, the land surface slope, and unsurfaced road density in a given area. The erodibility classes of various geology types are summarized in Table 4, while the slope classes are summarized in Table 5. The integration of these two variables (geology and slope) results in the N value, as given in Table 6.

#### Calculating the Sediment Delivery Index (S)

*Pre-Project.* The Sediment Delivery index is a relative index created to characterize sediment processes based on natural or background levels and to integrate the effects of unsurfaced roads on a given litho-subwatershed unit. The natural erodibility rating (N) is multiplied by the pre-project road density to calculate the pre-project Sediment Delivery index ( $S_{PRE}$ ) value for a specific litho-subwatershed unit. The raw index scores for each litho-subwatershed unit were weighted by a given unit’s share of subwatershed area in order to aggregate results to the subwatershed scale and ultimately to an action alternative scale.

*Post-Project.* The post-project Sediment Delivery index was calculated in the same manner as the pre-project index, but incorporates the density of new roads and transmission line corridors that would result from the project (see Figure 4). For this calculation, the length of new roads that would be constructed outside of the transmission line corridor was included along with the transmission line corridor length to arrive at a post-project road density within each litho-subwatershed unit. The post-project Sediment Delivery index is determined by multiplying the

post-project road density ( $R_{POST}$ ) by the natural erodibility rating (N) to calculate the post-project Sediment Delivery index ( $S_{POST}$ ). The calculation steps are summarized below.

N = Natural Erodibility Rating (see Table 6)

Weighting Factor:

$$W = \text{Area of Litho-Subwatershed Unit} / \text{Total Subwatershed Area}$$

Road Density:

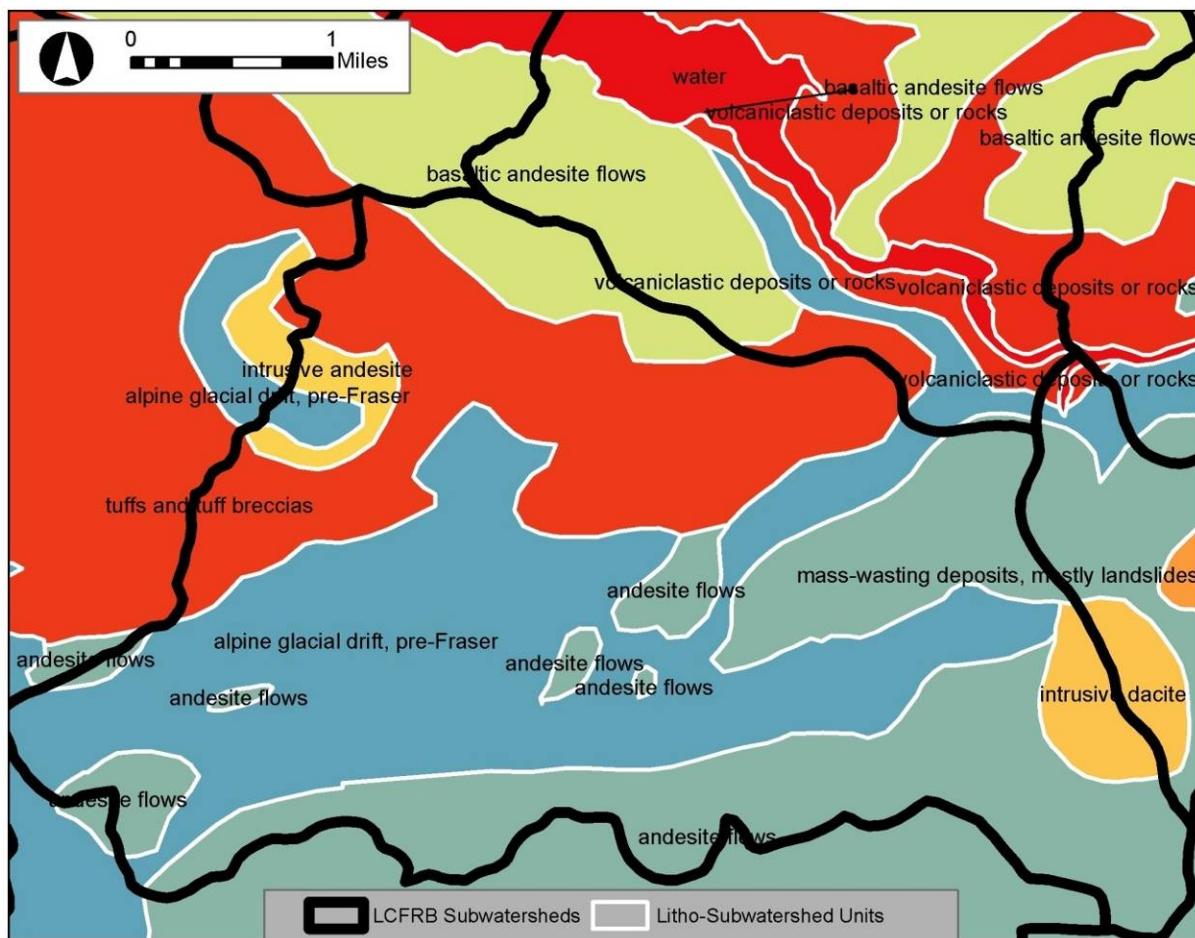
$R_{PRE}$  = Road Density within Litho-Subwatershed Unit based on Pre-project Conditions

$R_{POST}$  = Road Density within Litho-Subwatershed Unit based on Post-project Conditions

Sediment Delivery index:

$$\text{Sediment Delivery Index Based on Pre-project Conditions: } S_{PRE} = N * R_{PRE} * W$$

$$\text{Sediment Delivery Index Based on Post-project Conditions: } S_{POST} = N * R_{POST} * W$$



**Figure 3.** The geographic unit used for calculating the Sediment Delivery index, the litho-subwatershed unit, defined as an area of uniform geology within a given subwatershed. Results for the index (based on slope, erodibility of the geology and road density) were weighted by a given litho-subwatershed unit's area, relative to total subwatershed area.

**Table 4. Erodibility of underlying geology, as presented in the IWA methodology (LCFRB 2010a).**

Erodibility Class	Definition	Data Source	Score
High erodibility	Unconsolidated sediments of alluvial, glacial, or volcanic origin	IWA database	Uses IWA ratings
Moderate erodibility	Thinly bedded sedimentary rocks and pyroclastic deposits (i.e., volcanic materials not related to lava flows)	IWA database	Uses IWA ratings
Low erodibility	Massive igneous and sedimentary rocks	IWA database	Uses IWA ratings

**Table 5. Land surface slope classes, as defined in the IWA methodology (LCFRB 2010a).**

Rating	Definition	Data Source	Score
Steep slope	>65% slope	IWA database	Uses IWA ratings
Moderate slope	30-65% slope	IWA database	Uses IWA ratings
Low slope	<30% slope	IWA database	Uses IWA ratings

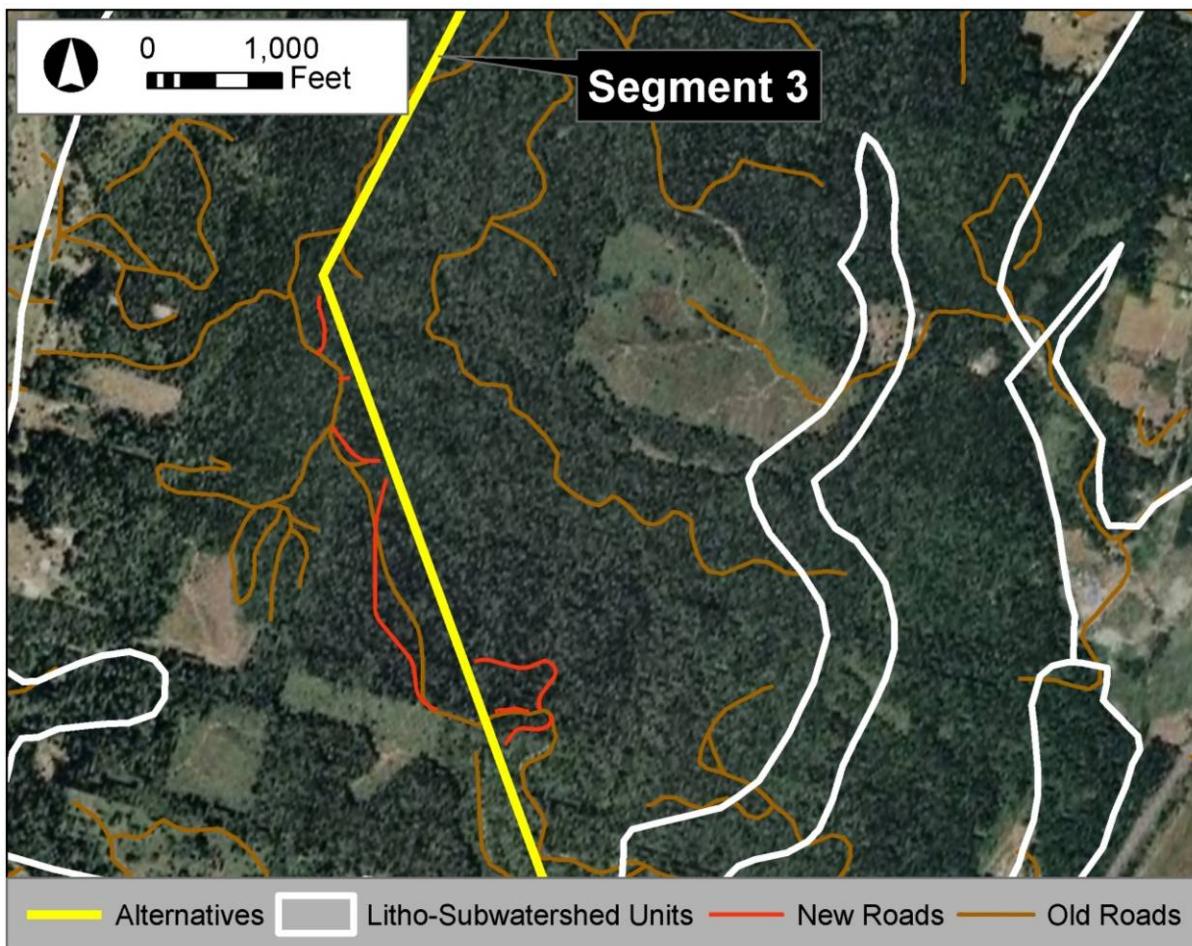
**Table 6. Natural erodibility rating (N) based on erodibility of underlying geology and slope of a given litho-subwatershed unit.**

Erodibility	Slope	Natural Erodibility Rating
Low	<30%	1
	30-65%	5
	>65%	10
Moderate	<30%	25
	30-65%	50
	>65%	75
High	<30%	50
	30-65%	75
	>65%	100

### Calculating the Change Index ( $\Delta S$ )

The final index calculation captures the difference between the pre- and post-project Sediment Delivery index values. By comparing pre- and post-project indices, we are able to discriminate between even minor changes in subwatershed-scale impairment.

$$\Delta S = S_{POST} - S_{PRE}$$



**Figure 4.** Example of pre- and post-project road density calculations, looking at existing unsurfaced roads (brown lines) and new roads (red lines) and lengths of the various segments of the transmission lines (yellow) within each litho-subwatershed unit (white polygon).

### **Results**

The results of the sediment analysis are presented by alternative and option (Table 7). Generally, the largest impacts to sediment delivery would occur in the West and Central alternatives and options, while the Crossover and East alternatives and options are predicted to have lesser impacts. The raw change in index values range from 94.2 to 367.5 by alternative. Table 7 shows the mean percentage change from pre-project condition from results calculated at the subwatershed scale. The percentage change ranges from 0.00% to 0.25%.

## **Discussion**

The various subwatersheds and geology types crossed by the action alternatives and options have different natural erodibility. Generally, the West Alternative and options would cross more erodible terrain, while the East Alternative and options would cross less erodible geology. Although the West Alternative and options are associated with the least amount of unsurfaced road construction, they would cause the highest potential impact to sediment delivery. The West Alternative and options would cross a large number of litho-subwatershed units with natural erodibility rating values of 25 and 50 (see Table 6). The results show that alternatives requiring the construction of access roads in more erodible terrain would result in higher sediment delivery impacts. The highest change values are found in the West Alternative and options, while the East and Central alternatives and options were found to have the lowest change index values.

The approach developed for estimating impacts to sediment delivery is based on the IWA methods (LCFRB 2010a). However, in order to provide enough sensitivity to detect the impact, the final index calculation was converted from a categorical score (functional / moderately impaired / impaired) to a continuous score. An evaluation using the IWA categorical scoring approach would not have been able to detect the changes to sediment delivery caused by the impacts associated with the various alternatives and options. Using the more sensitive approach developed for this analysis, the impacts to sediment delivery were detectable. However, for all alternatives and options, the post-project sediment delivery represents a very small percentage increase from pre-project conditions. Long-term changes in watershed conditions would therefore be minor; however, local impacts could occur that result in locally high impairment to sediment functions.

**Table 7. Sediment Delivery index values for action alternatives and options. Values are sorted by increasing index score, from least increase in sediment delivery to most.**

Alternative	New Corridor Length (mi)	New Access Road (mi)	S <sub>PRE</sub>	S <sub>POST</sub>	Sediment Delivery Index	Percent Change
East Option 2	75.0	20.3	240,523	240,617	94	0.00%
Central Option 3	70.1	26.2	265,184	265,280	97	0.15%
East Option 1	72.2	23.1	274,240	274,344	105	0.01%
East Alternative	74.0	22.5	264,581	264,687	106	0.00%
East Option 3	75.1	21.9	264,581	264,687	106	0.00%
Central Option 2	73.7	28.8	248,995	249,109	114	0.16%
Central Option 1	78.4	27.6	246,699	246,818	119	0.14%
Central Alternative	75.9	26.8	245,340	245,459	119	0.15%
Crossover	72.6	21.0	319,932	320,064	132	0.17%
Crossover Option 1	76.8	21.9	319,932	320,077	145	0.17%
Crossover Option 2	77.8	21.2	323,164	323,310	146	0.16%
Crossover Option 3	76.9	21.8	323,164	323,310	146	0.16%
West Option 3	71.8	18.4	595,292	595,587	295	0.23%
West Option 2	67.7	16.0	563,210	563,513	303	0.25%
West Alternative	66.2	16.0	554,446	554,807	361	0.25%
West Option 1	66.2	16.4	566,590	566,957	368	0.25%

## RIPARIAN IMPACT ASSESSMENT

The Riparian Impact Assessment evaluates the potential effects of alternative transmission line routes on loss of riparian function along fish-bearing streams. Any given stream reach might support none, some, or all of four listed salmon and steelhead species.

This assessment used the WaFPB Manual (2011b) method for riparian function. These procedures define riparian function narrowly, focusing on two specific processes: 1) the recruitment of large woody debris, and 2) the provision of stream shade. Riparian function was interpreted from recent aerial photography at each crossing. Using this protocol provides systematic means of characterizing riparian function potentially impacted by different transmission routes in a quantitatively rigorous and transparent manner.

Using these interpretations, two index values were developed to reflect the potential impacts of alternative transmission corridor segments on loss of riparian function along fish-bearing streams. Index values were based on the potential impact of vegetation clearing at transmission line crossings on habitat conditions and how those impacts affect:

1. Near-term riparian function, and
2. Long-term riparian function.

Index values reflect potential impacts to riparian function along the stream reach immediately adjacent to the clearing at each transmission line crossing. The two index values capture a number of important factors when analyzing crossing impacts, including the length of forested riparian vegetation cleared along the fish-bearing stream, site characteristics limiting vegetation development, dominant vegetation types, average tree size classes, stand density classes, channel migration zones, stream width, canopy closure, elevation, and Washington Department of Ecology (WaDOE) stream temperature standards.

### ***Background***

Removal of forested vegetation along transmission line right-of-way corridors could reduce streamside shade and large woody debris recruitment. Some loss could be permanent since operations and maintenance would include periodic removal of tree saplings and other vegetation within transmission line right-of-way corridors in forested areas. This could result in long-term reductions in riparian function. Riparian vegetation can moderate stream temperature year-round (Beschta et al. 1987, Murphy and Meehan 1991) and riparian forests are a source of large woody debris which increases channel complexity (Bilby and Bisson 1998). Shade loss from streamside vegetation removal can lead to higher stream water temperature (Li et al. 1994) which can decrease fish survival (Lantz 1971, Beschta et al. 1987). Removal of future wood sources can impact fish growth and survival through simplification of habitat and destabilization of channel beds (Bisson et al. 1987, Grant et al. 1990) as well as a reduction in nutrients (Naiman et al. 1992, Spence et al. 1996).

This assessment focuses on the loss of riparian function from transmission line corridor crossings at fish-bearing streams. The length of stream cleared is at least 150 ft and, because of stream orientation and sinuosity, it is often greater. At these scales, loss of wood recruitment could be enough to significantly alter geomorphic processes (Montgomery et al. 2003) and the loss of stream shade could be enough to warm streams to levels harmful to fish inhabiting the

stream reach (Cristea and Janisch 2007). In comparison, riparian clearing would not be required at substations. Clearing of forested vegetation would be required at ten or fewer new access road crossings for any alternative or alternative options; clearing would be limited to 30 ft. Clearing would be required at transmission line corridor crossings at non-fish-bearing streams, but effects from loss of riparian function on instream wood and stream temperature would be attenuated (Caldwell et al. 1991, Reeves et al. 2003). Many would be excluded from WaFPB riparian assessments because their influence on fish-bearing streams is insignificant.

## ***Methods***

### Data

Locations and lengths of stream crossings were derived from the WaDNR database WCHYDRO from the Forest Practices Application Review System (FPARS). This reference data set, used for forest practices applications, represents fish habitat according to WAC 222-16-030 at a 1:24,000 hydrography scale or finer. Fish-bearing streams can include anadromous and non-anadromous species. A stream crossing includes all connected fish-bearing stream reaches intersected by the transmission line corridor.

Elevations at stream crossings were derived from United States Geological Survey (USGS) 1:24,000 topographic maps available from Environmental Systems Research Institute (ESRI). The stream elevation in the middle of the corridor was used. WaDOE stream temperature standards were derived from the WaDNR database STRMTEMP available from FPARS. This data set is also used in forest practice applications and represents stream temperature classifications designated in WAC 173-201A-030 at a scale of 1:250,000 polygon scale or finer.

Aerial photo interpretations of riparian vegetation were conducted off of i-cubed Nationwide Prime high resolution (1 meter or better) aerial photography imagery available from ESRI. The i-cubed Nationwide Prime imagery is a seamless, color mosaic of various commercial and government imagery sources, including the best available USDA Farm Services Agency National Agriculture Imagery Program imagery and enhanced versions of USGS Digital Ortho Quarter Quad imagery for other areas.

### Indices

The Near-term Riparian Function index quantifies the potential for near-term riparian function loss. Index values were determined on a crossing-by-crossing basis using riparian function ratings determined via Table 8. Ratings are based on large woody debris (LWD) recruitment potential and stream shade hazard determined following WaFPB Manual (2011b) protocols. Ratings are converted from categorical to continuous variables to represent the relative loss in riparian function. These scalars are approximate but meaningful relative to one another. Crossings with high function ratings have greater loss than crossings with low ratings. Non-forest crossings are assigned a rating of zero (0). Function ratings are multiplied by the length of forested vegetation cleared at each crossing, then summed over all crossings to yield the index value for an alternative.

**Table 8. Crossing-scale riparian function ratings based on LWD recruitment potential and stream shade hazard.**

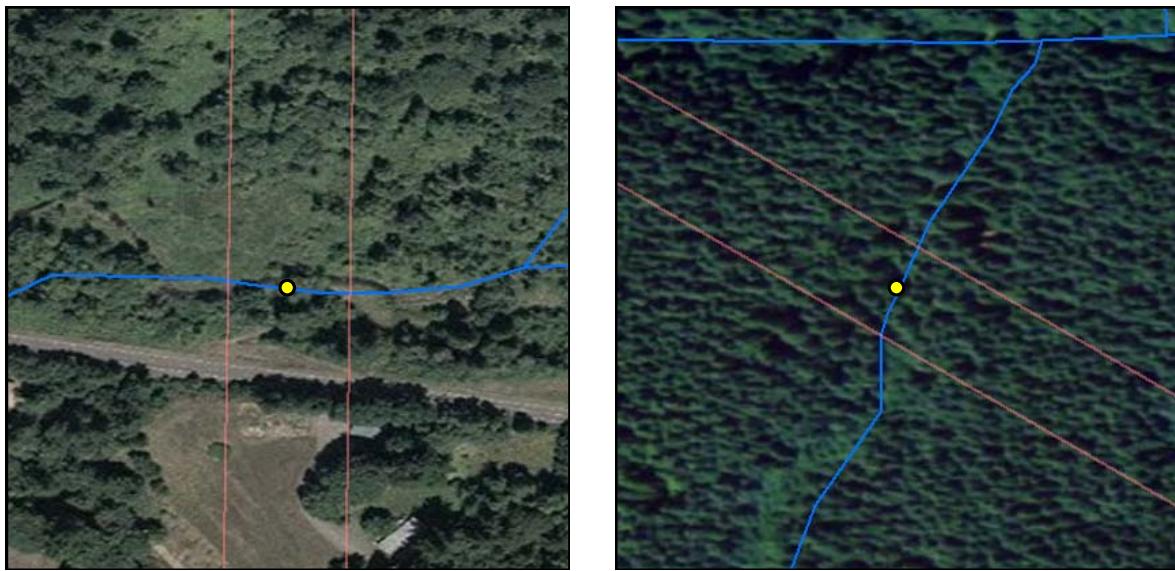
Shade Hazard	LWD Recruitment Potential		
	High	Moderate	Low
Low	High (1)	Moderate (0.67)	Low (0.33)
High	Moderate (0.67)	Low (0.33)	Low (0.33)

The near-term LWD recruitment potential rating is based on the dominant vegetation types, average tree size classes, and stand density classes found within 100 ft of the stream at each crossing. We classified near-term LWD recruitment potential into low, moderate, and high categories using the assessment protocols in the WaFPB Manual (2011b) (Table 9). Determinations were based on aerial photo interpretation at each crossing. Low LWD recruitment potential is associated with hardwood dominated stands and high LWD recruitment potential is associated with mixed or conifer dominated stands (see examples in Figure 5).

**Table 9. LWD recruitment potential rating based on species composition, average tree size class, and stand density class (according to WaFPB 2011b).**

Average Tree Size Class	Species Composition and Stand Density Classes					
	> 70% Hardwood		Mixed		> 70% Conifer	
	Sparse	Dense	Sparse	Dense	Sparse	Dense
Small <12" DBH	Low	Low	Low	Low	Low	Low
Moderate 12 to 20"	Low	Moderate	Moderate	High	Moderate	High
Large >20" DBH	Low	Moderate	Moderate	High	Moderate	High

The stream shade hazard rating is based on canopy closure, elevation, and WaDOE stream temperature standards. We classified shade hazard into low and high categories using the assessment protocols in the WaFPB Manual (2011b) (Table 10). Canopy closure determinations were based the visibility of the stream surface and stream banks. Determinations were based on aerial photo interpretation at each crossing. Elevations were determined from USGS topographic maps. WaDOE stream temperature standards were determined from FPARS data. High shade hazards are often associated with wider streams or streams with wide, active channel migration zones where adequate canopy cover over the stream is difficult to achieve. They are also associated with low elevation streams where more canopy cover is required to achieve shade targets. Low shade hazards are often found along streams with narrower, confined stream channels and/or high canopy closure (see Figure 6).



**Figure 5.** Example of low LWD recruitment potential at a fish-bearing stream crossing (left, crossing 25-10) and high LWD recruitment potential (right, crossing K-6). Scale 1:4,800.

**Table 10.** Stream shade hazard rating based on canopy closure, elevation, and WaDOE stream temperature standard (according to WaFPB 2011b).

Elevation (ft)	Canopy Closure				
	> 90%	70-90%	40-70%	20-40%	0-20%
<i>Class AA WaDOE Standard - 16 deg C</i>					
0-320	Low	High	High	High	High
320-680	Low	Low/High	High	High	High
680-1160	Low	Low	High	High	High
1160-1640	Low	Low	Low/High	High	High
1640-1960	Low	Low	Low/High	High	High
1960-2400	Low	Low	Low	High	High
<i>Class A WaDOE Standard - 18 deg C</i>					
0-120	Low	Low/High	High	High	High
120-440	Low	Low	High	High	High
440-680	Low	Low	Low/High	High	High
680-1000	Low	Low	Low/High	High	High
1000-1320	Low	Low	Low	High	High
1320-1640	Low	Low	Low	Low/High	High
1640-1960	Low	Low	Low	Low	High
1960-2320	Low	Low	Low	Low	Low/High
2320+	Low	Low	Low	Low	Low



**Figure 6.** Example of high stream shade hazard at a fish-bearing stream crossing (left, crossing K-8) and low stream shade hazard (right, crossing 9-25). Scale 1:4,800.



**Figure 7.** Examples of adjacent non-forest land use limiting to LWD recruitment potential and not to stream shade at a fish-bearing stream crossing (left, crossing M-2) and limiting to LWD recruitment potential and stream shade (right, crossing 36B-1). Scale 1:4,800.

The Long-term Riparian Function index quantifies the potential for long-term riparian function loss. Index values were determined in the same manner as the Near-term Riparian Function index; however, they are based on projections of future riparian function summarized in Table 11. These projections incorporate forest successional pathways in the WaFPB Manual (2011b). Generally, as stands develop, conifer species composition increases through natural succession, as does average tree size and stand density. However, site factors can limit the development of high riparian function. High LWD recruitment potential and low stream shade hazard can be

limited by adjacent non-forest land uses (see Figure 7). Low stream hazard can also be limited along wider streams or streams with wide, active channel migration zones. Site limitations to LWD and shade were interpreted based on aerial photo interpretation.

**Table 11. Long-term riparian function based on near-term LWD recruitment potential and stream shade and limitations to LWD recruitment potential and/or stream shade.**

Near-term LWD Recruitment Potential and Stream Shade Hazard	Long-term LWD Species Composition, Recruitment Potential, and Stream Shade Hazard			
	No Site Limitations	Limitations for LWD	Limitations for Shade	Limitations for Both
<b>Non-forested</b>	Non-forested	Non-forested	Non-forested	Non-forested
<b>Predominantly Hardwood Low LWD Potential High Shade Hazard</b>	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard	Conifer/Hardwood Mixed High LWD Potential High Shade Hazard	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard
<b>Predominantly Hardwood Low LWD Potential Low Shade Hazard</b>	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard
<b>Predominantly Hardwood Moderate LWD Potential High Shade Hazard</b>	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	Conifer/Hardwood Mixed High LWD Potential High Shade Hazard	Conifer/Hardwood Mixed High LWD Potential High Shade Hazard
<b>Predominantly Hardwood Moderate LWD Potential Low Shade Hazard</b>	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard
<b>Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard</b>	Predominantly Conifer High LWD Potential Low Shade Hazard	Predominantly Conifer Moderate LWD Potential Low Shade Hazard	Predominantly Conifer High LWD Potential High Shade Hazard	Predominantly Conifer Moderate LWD Potential High Shade Hazard
<b>Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard</b>	Predominantly Conifer High LWD Potential Low Shade Hazard	Predominantly Conifer Moderate LWD Potential Low Shade Hazard	Predominantly Conifer High LWD Potential Low Shade Hazard	Predominantly Conifer Moderate LWD Potential Low Shade Hazard
<b>Conifer/Hardwood Mixed High LWD Potential High Shade Hazard</b>	Predominantly Conifer High LWD Potential Low Shade Hazard	Predominantly Conifer High LWD Potential Low Shade Hazard	Predominantly Conifer High LWD Potential High Shade Hazard	Predominantly Conifer High LWD Potential High Shade Hazard
<b>Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard</b>	Predominantly Conifer High LWD Potential Low Shade Hazard	Predominantly Conifer High LWD Potential Low Shade Hazard	Predominantly Conifer High LWD Potential Low Shade Hazard	Predominantly Conifer High LWD Potential Low Shade Hazard
<b>Predominantly Conifer Moderate LWD Potential High Shade Hazard</b>	Predominantly Conifer High LWD Potential Low Shade Hazard	Predominantly Conifer Moderate LWD Potential Low Shade Hazard	Predominantly Conifer High LWD Potential High Shade Hazard	Predominantly Conifer Moderate LWD Potential High Shade Hazard
<b>Predominantly Conifer Moderate LWD Potential Low Shade Hazard</b>	Predominantly Conifer High LWD Potential Low Shade Hazard	Predominantly Conifer Moderate LWD Potential Low Shade Hazard	Predominantly Conifer High LWD Potential Low Shade Hazard	Predominantly Conifer Moderate LWD Potential Low Shade Hazard
<b>Predominantly Conifer High LWD Potential High Shade Hazard</b>	Predominantly Conifer High LWD Potential Low Shade Hazard	Predominantly Conifer High LWD Potential Low Shade Hazard	Predominantly Conifer High LWD Potential High Shade Hazard	Predominantly Conifer High LWD Potential High Shade Hazard
<b>Predominantly Conifer High LWD Potential Low Shade Hazard</b>	Predominantly Conifer High LWD Potential Low Shade Hazard	Predominantly Conifer High LWD Potential Low Shade Hazard	Predominantly Conifer High LWD Potential Low Shade Hazard	Predominantly Conifer High LWD Potential Low Shade Hazard

## Results

Appendix B lists 254 fish-bearing stream crossings encountered along all alternative transmission line routes. For each crossing, the following information is provided:

- Location of the intersection of the stream and the transmission route centerline
- Length of stream within the 150 ft wide transmission line corridor
- Length of stream cleared of forested vegetation within the corridor
- Near-term species composition, LWD recruitment potential, and shade hazard
- Near-term riparian function rating according to Table 8
- Limitations to development of long-term riparian function
- Long-term species composition, LWD recruitment potential, and shade hazard
- Long-term riparian function rating according to Table 8

Table 12 summarizes the Near-term Riparian Function index for each alternative and alternative option. The table also summarizes the total number of fish-bearing streams encountered along each alternative or alternative option, the number of non-forested stream crossings, length of stream cleared of forested vegetation, average crossing-scale riparian function rating, the near-term index value, and the ratio of the index value to the total length of stream cleared. Alternatives and options are sorted from the lowest to greatest index value, which corresponds to least riparian function loss to most.

**Table 12. Near-term Riparian Function index for action alternatives and options. Values are sorted by increasing index score, from least riparian function loss to most.**

Alternative	Total Number of Crossings	Total Non-forested Crossings	Total Length of Stream Cleared (ft)	Average Near-term Riparian Function Rating	Near-term Riparian Function Index	Ratio of Index to Stream Length Cleared
West Option 2	75	29	12,169	0.31	5,592	46%
West Option 1	73	27	13,029	0.32	5,926	45%
West Alternative	71	24	13,415	0.34	6,054	45%
West Option 3	79	28	12,910	0.33	6,153	48%
East Option 1	54	8	10,007	0.60	7,483	75%
Crossover Alternative	76	21	13,343	0.51	9,291	70%
East Option 3	63	7	11,061	0.72	9,340	84%
East Alternative	59	7	11,076	0.71	9,344	84%
Crossover Option 2	80	24	13,627	0.49	9,385	69%
Crossover Option 3	80	22	14,198	0.50	9,588	68%
Crossover Option 1	79	21	15,418	0.51	10,027	65%
East Option 2	66	7	12,326	0.72	10,312	84%
Central Option 2	69	6	14,048	0.69	10,550	75%
Central Option 3	66	6	13,482	0.76	11,141	83%
Central Alternative	74	6	14,841	0.73	12,006	81%
Central Option 1	76	6	15,430	0.73	12,373	80%

Near-term Riparian Function index values are substantially different at the extremes and exhibit a more or less uniform rate of decrease from the highest to lowest score. Despite these differences, clearing of forested vegetation is measurable along all alternatives and options. When scaled by the riparian function rating, it is approximately equal to the loss of 1 to 2.5 miles of highly functioning riparian vegetation; this is a high fraction of the forested stream length cleared. This level of loss could have measurable impact on fish populations. Values were lowest for the West Alternative and options and greatest for the Central Alternative and options. The East and Crossover Alternative and options were in the middle of the overall ranking.

Table 13 summarizes the Long-term Riparian Function index for each alternative and alternative option. The table also summarizes the total number of fish-bearing streams encountered along each alternative or alternative option, the number of non-forested stream crossings, length of stream cleared of forested vegetation, average crossing-scale riparian function rating, the long-term index value, and the ratio of the index value to the total length of stream cleared. Alternatives and options are sorted from the lowest to greatest index value which corresponds to least riparian function loss to the most.

**Table 13. Long-term Riparian Function index for action alternatives and options. Values are sorted by increasing index score, from least riparian function loss to most.**

Alternative	Total Number of Crossings	Total Non-forested Crossings	Total Length of Stream Cleared (ft)	Average Long-term Riparian Function Rating	Long-term Riparian Function Index	Ratio of Index to Stream Length Cleared
East Option 1	54	8	10,007	0.71	8,559	86%
West Option 2	75	29	12,169	0.46	9,024	74%
West Option 1	73	27	13,029	0.47	9,112	70%
West Alternative	71	24	13,415	0.49	9,239	69%
West Option 3	79	28	12,910	0.50	9,750	76%
East Alternative	59	7	11,076	0.80	10,252	93%
East Option 3	63	7	11,061	0.82	10,287	93%
Crossover Alternative	76	21	13,343	0.60	11,319	85%
Crossover Option 2	80	24	13,627	0.58	11,413	84%
East Option 2	66	7	12,326	0.82	11,546	94%
Crossover Option 3	80	22	14,198	0.61	12,174	86%
Crossover Option 1	79	21	15,418	0.60	12,200	79%
Central Option 3	66	6	13,482	0.84	12,363	92%
Central Option 2	69	6	14,048	0.82	12,575	90%
Central Alternative	74	6	14,841	0.87	14,207	96%
Central Option 1	76	6	15,430	0.87	14,797	96%

Long-term Riparian Function index values are substantially different at the extremes and exhibit a more or less uniform rate of decrease from the highest to lowest score. When scaled by the riparian function rating, it is approximately equal to the loss of 1.5 to 3 miles of highly-functioning riparian vegetation; this is a high fraction of the forested stream length cleared. This level of loss could have measurable impact on fish populations. The rankings according to the long-term index nearly match those using the near-term index. The most notable exception is that the East Alternative Option 1 would have the lowest riparian function loss. Otherwise, the West Alternative and options would have the lowest riparian function loss compared to the others.

### ***Discussion***

By using consistent assessment procedures informed by consistent data sources and conducted by one individual, results are comparable among alternatives and options. This assessment was a desktop exercise and more accurate determinations can be made through field investigation. Specifically, better information could be obtained about the location of streams within transmission line corridors, location of riparian assessment areas, stand development potential, site limitations to LWD recruitment potential and stream shade hazard, and stream shade provided by the existing canopy. Any of these could improve determination of riparian function, but this uncertainty affected all alternatives and options more or less equally. Therefore, the relative ranking of alternatives and alternative options is reliable for planning purposes.

While they appear similar, the near-term and long-term indices reflect different impacts. The near-term index reflects impacts to current riparian conditions—conditions that have been degraded by past forest management practices and continue to be limited by non-forest land uses that encroach on the riparian assessment areas. In comparison, the long-term index reflects impacts to potential riparian conditions—conditions that could result through natural succession with no further degradation due to non-forest land uses. While there are very similar outcomes from the two indices, reasons for the two outcomes differ.

The strongest predictor of near-term riparian function loss is the average near-term riparian function rating. As the average riparian function increases, so does the overall loss of riparian function that would occur with transmission line corridor. In the near-term, quality matters more than quantity. In comparison, the strongest predictor of long-term riparian function loss is the total length of stream cleared. As the length of stream cleared increases, so does the overall loss of riparian function. The spread between the high and low average riparian function decreases; and so does its importance. In the long-term, quantity matters more than quality.

The greatest increase in riparian function, near-term to long-term, would occur along the West Alternative and options. Despite higher numbers of non-forested stream crossings and greater limitations to LWD and shade development, these crossings currently have the lowest near-term riparian function. Adjoining non-forest land use pressures have played a large role in degrading riparian function. Thus, they have the greatest room for improvement. In comparison, riparian function for the other alternatives and alternative options are nearer to peak levels. The room for improvement along the other routes is limited.

This has little effect on the overall ranking. The lowest average riparian function ratings occur along the West Alternative and options, which would have some of the lowest levels of stream cleared. Many stream crossings are located within existing transmission line corridors and many others are located in agricultural or developed settings. Where there are forested crossings, hardwood species composition is greater. Non-forested land uses and wider streams and lower stream elevations limit riparian function and effectiveness. These factors lead to lower riparian function. When multiplied by lower length of stream cleared, index values are lower.

In comparison, the other alternatives and options have higher average riparian function ratings and most would have a greater length of stream cleared. They tend to have greater conifer species composition, fewer limitations from non-forested land uses, and narrower streams and higher elevations. These factors lead to higher LWD recruitment potential and lower stream shade hazards that translate to higher riparian function which, when multiplied by greater length of stream cleared, leads to higher index values. The one notable exception is East Alternative Option 1. This option would have the least length of stream cleared among all alternatives and options. Because of this, riparian function loss ranks relatively low to lowest.

Overall, the project would clear forested vegetation along approximately 2 to 3 miles of fish-bearing streams. Permanent changes to riparian function at project crossings could occur through the loss of large woody debris recruitment potential and stream shade. At the crossing scale, a range of large woody debris recruitment potential and stream shade would be lost along any project alternative. However, this loss of riparian function could be buffered by riparian function provided at the watershed scale.

## FLOODPLAIN IMPACT ASSESSMENT

The Floodplain Impact Assessment evaluates the potential effects of alternative transmission line routes on loss of floodplain function along fish-bearing streams. Any given stream reach might support none, some, or all of four listed salmon and steelhead species.

This assessment used an interpretation of floodplain areas using Federal Emergency Management Agency (FEMA) 100-yr floodplain mapping, Light Detection and Ranging (LiDAR) imaging, and aerial photography. The protocols employed provide a systematic means of characterizing floodplain function potentially impacted by different transmission routes in a quantitatively rigorous and transparent manner.

Using these interpretations, a single index value was developed to reflect the potential loss of floodplain functions due to impacts from alternative transmission corridor segments, towers, and access roads. The following three types of impacts were evaluated and incorporated into the index:

1. reduction in forest vegetation within floodplains;
2. number and footprint area of new towers within the floodplain; and,
3. area of new or reconstructed roads within the floodplain.

Index values reflect the potential effect of transmission line routes on key indicators of floodplain function.

### ***Background***

Floodplains provide numerous important functions related to stream habitat and ecosystem health. Floodplains help to absorb stream energy during floods, provide for nutrient exchange, and provide habitat for aquatic and terrestrial species (Bolton and Shellberg 2001). Floodplains are also closely related to channel migration zones (CMZs) and frequently occupy a similar area on the landscape. Although CMZs were not delineated separately for this analysis, the assessment of floodplain impacts is assumed to also generally address impacts to CMZs. CMZs are important for stream geomorphic function and long-term formation of aquatic and floodplain habitats. As streams migrate and adjust within the CMZ, off-channel habitats are formed, new mainstem habitats are created, and gravel and large woody debris are recruited to the stream channel (Bolton and Shellberg 2001).

### ***Methods***

This assessment calculated floodplain acreage and forest cover that would be affected by transmission line route alternatives. It also quantified the number and acreage of new towers and the length and acreage of new or reconstructed roads within the floodplain. Values were calculated first at the stream crossing scale and were then aggregated up to the alternative scale.

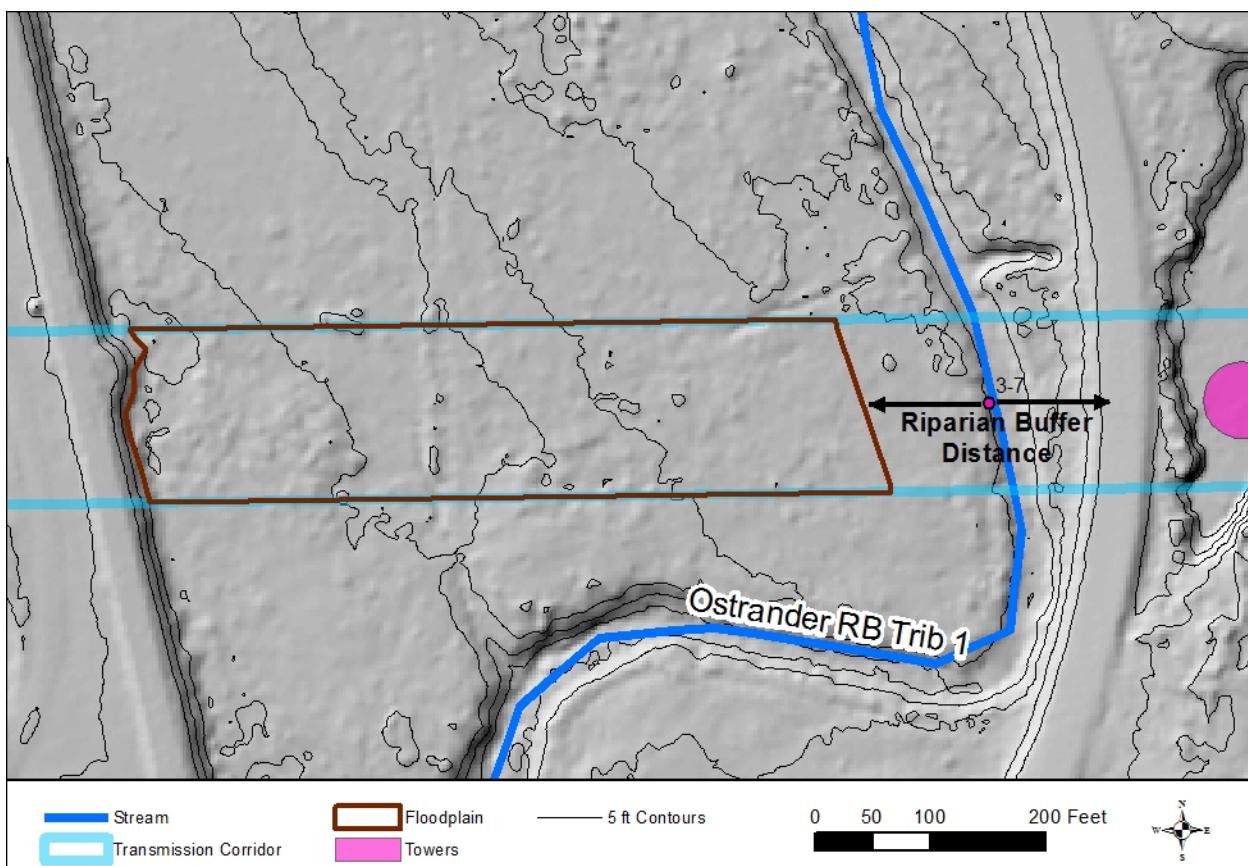
### **Qualifying Floodplains**

All fish-bearing stream crossings were considered for use in this analysis. To qualify as a floodplain for this analysis, floodplain areas must extend greater than 100 lineal feet from the stream edge (see below for determination of floodplain areas). Impacts associated with fish-bearing stream crossings with floodplains less than 100 ft wide are addressed in the Riparian

Impact Assessment (see above). To avoid duplication with the Riparian Function index, this analysis evaluates only those portions of the floodplain extending beyond 100 feet from the stream edge.

#### Determining Floodplain Area

For each qualifying stream crossing, the floodplain area within the transmission line corridor was delineated in a Geographic Information System (GIS) using LiDAR and aerial photo interpretation. Indicators used to identify floodplain areas included flood overflow channels, signatures of historical channel locations, and floodplain elevations in relation to the stream elevation. FEMA 100-year floodplains were used to help delineate the floodplain in areas where these data were available. Once the entire floodplain area polygon was delineated for a crossing, the portion of the floodplain within 100 ft of the stream edge was removed from the area to avoid duplication with the riparian assessment. See Figure 8 for an example of the floodplain delineation.



**Figure 8. Example of floodplain delineation within a transmission line corridor using LiDAR digital elevation data.**

#### Quantifying Impacts to Floodplain Vegetation

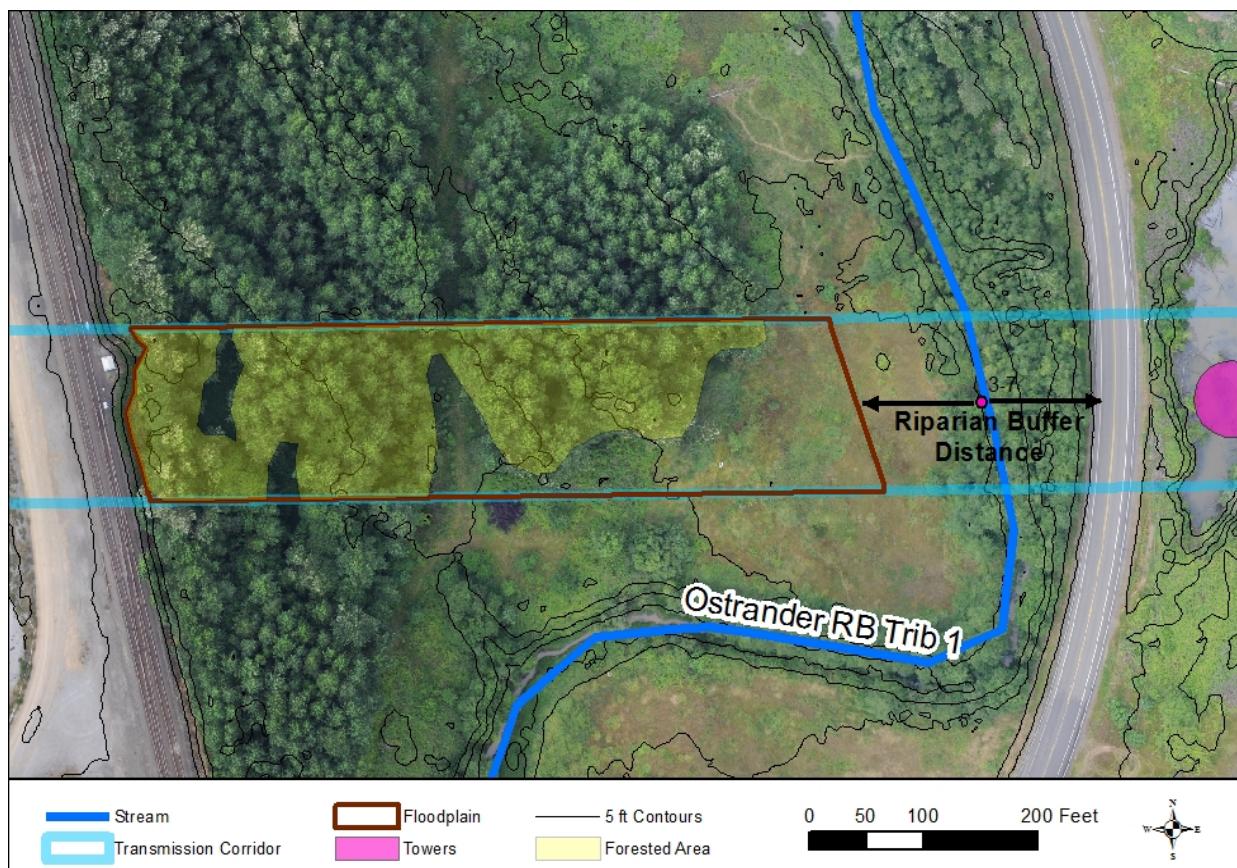
The amount of forest vegetation that would be cleared within transmission line corridors as a result of project impacts was calculated within floodplain areas at each crossing. This was calculated as the acreage of canopy cover for trees above approximately 3 feet in height. This was performed using aerial photo interpretation. See Figure 9 for an example of the delineation of forested floodplain vegetation.

### Calculating Floodplain Tower Area

The number and area of new, additional transmission line towers within delineated floodplains was tabulated. Existing towers to be removed or replaced was accounted for so that the number and area of towers represents the net addition of new towers. Tower area is intended to approximate the permanent footprint of the tower. To be consistent with analyses in other DEIS sections, this was calculated as a 66-foot diameter circle.

### Calculating Floodplain Road Area

The length and area of new or reconstructed roadways within floodplains was calculated for each delineated floodplain area at each crossing. To be consistent with analyses in other DEIS sections, road area was calculated assuming a 30-foot width for new roads and a 20-foot width for reconstructed roads. These road lengths and areas represent only the portion of roads located within transmission corridors, and do not capture roads in floodplains outside corridors. For this reason, a second calculation was performed, which is the total length of new or reconstructed roads within the FEMA-designated 100-year floodplain, whether they are within or outside of transmission corridor right-of-ways.



**Figure 9. Example of the delineation of forested floodplain vegetation that would be cleared within a transmission line corridor.**

### Calculating the Total Floodplain Impact Area Index

A composite index of floodplain impact was calculated by summing the area of impact to floodplains due to forest vegetation clearing, tower construction, and road construction within the transmission line corridor. This value was calculated at each transmission line crossing by summing the area values for: 1) impacts to floodplain vegetation, 2) floodplain roads (within corridors), and 3) towers within floodplains.

### **Results**

Out of a total of 254 fish-bearing crossings, 60 crossings had qualifying floodplains that were used in this assessment (see Appendix C for a listing). A summary of the total number of crossing per alternative and alternative option, along with the number of qualifying floodplain crossings used in this assessment, is presented in Table 14. The West Alternative and options would have the greatest number of floodplain crossings, followed by the Crossover Alternative and options.

The results of the Floodplain Impact Assessment for all alternatives are presented in Table 15. The Total Floodplain Impact Area index values are the sum of acreages for vegetation clearing, new towers, and new or reconstructed roadways within the portion of the floodplain crossed by the transmission line corridor. The West Alternative and options would have the greatest total impact area as well as the greatest values for all impact categories. The East Alternative and options would generally have the second-greatest impact values. The East and Central alternatives and options would have the least amount of total impact area but would fall within the middle of the range with respect to impacts to vegetation. The Crossover Alternative and options would generally have the least impact to vegetation. Road and tower impacts would be similar among the East, Central, and Crossover alternatives and options.

**Table 14. Summary of total crossings (fish-bearing) and number of qualifying floodplain crossings by alternative. Values are sorted by number of qualifying floodplain crossings; the alternatives and options with the greatest numbers of floodplain crossings are listed at the bottom.**

Alternative	Total Number of Crossings	Number of Qualifying Floodplain Crossings
Central Option 2	77	14
East Option 1	64	14
Central Option 3	72	14
East Option 3	69	14
East Option 2	72	14
Central Alternative	81	15
Central Option 1	85	15
East Alternative	65	16
Crossover Alternative	87	19
Crossover Option 1	90	19
Crossover Option 2	91	21
Crossover Option 3	91	21

Alternative	Total Number of Crossings	Number of Qualifying Floodplain Crossings
West Option 2	80	22
West Alternative	76	22
West Option 3	85	24
West Option 1	78	25

**Table 15. Total Floodplain Impact Area index for action alternatives and options. Values are sorted by increasing impact area.**

Alternative	Total Floodplain Area (acres) <sup>1</sup>	Impacts to Floodplain Vegetation (acres) <sup>2</sup>	Number of New Additional Towers <sup>3</sup>	New or Reconstructed Roads in Corridor (lineal ft) <sup>4</sup>	New or Reconstructed Roads in FEMA 100-yr Floodplain (lineal ft) <sup>5</sup>	Total Floodplain Impact Area (acres) <sup>6</sup>
Central Option 2	26.7	6.3	5	2,671	4,434	7.7
Crossover Alternative	40.8	7.3	8	2,932	8,835	9.0
East Option 1	32.5	7.9	7	2,675	4,598	9.1
Central Alternative	28.0	8.1	4	2,138	5,159	9.2
Central Option 1	28.0	8.1	4	2,138	5,159	9.2
Crossover Option 2	41.5	7.7	8	2,932	8,835	9.4
Crossover Option 3	41.6	7.8	8	2,932	8,835	9.5
Central Option 3	30.6	7.9	4	3,087	6,317	9.5
East Option 3	28.7	9.1	5	2,455	5,159	10.2
East Option 2	29.0	9.3	5	2,455	5,159	10.4
Crossover Option 1	50.3	8.5	13	3,417	8,745	10.7
East Alternative	29.6	9.8	6	2,455	5,159	10.9
West Option 2	73.2	11.4	18	5,911	27,605	15.3
West Option 3	73.6	11.7	19	5,911	27,883	15.6
West Alternative	88.2	12.6	23	7,657	31,702	18.0
West Option 1	113.8	15.9	27	8,578	42,128	21.9

<sup>1</sup>Total floodplain area (beyond the 100-ft riparian buffer) crossed by the transmission corridor at qualifying stream crossings.

<sup>2</sup>Existing forest canopy cover within the floodplain area that is greater than approximately 3 feet in height.

<sup>3</sup>Represents net additional towers within the floodplain area. Towers that are replaced or relocated are not included.

<sup>4</sup>Represents length of new or reconstructed roads within the floodplain area.

<sup>5</sup>Represents length of new or reconstructed roads within FEMA-designated 100-yr floodplains. Includes roads within and outside transmission corridors.

<sup>6</sup>Sum of potential floodplain impacts within the transmission line corridor based on acreage of vegetation clearing, towers, and roads. Assumes 30 ft width for new roads, 20 ft width for reconstructed roads, and a 66-ft diameter circle for towers. Overlapping impact areas were accounted for in the summed values.

## ***Discussion***

The results of the Floodplain Impact Assessment reflect the pattern of floodplain topography and existing land-use conditions across the study area. The West Alternative and options have the highest total impact areas (see Table 15) due to a larger number of floodplain crossings (see Table 14) and route segments that cross broad floodplain areas within the lower portions of large river systems, including the Lewis, East Fork Lewis, Salmon Creek, and Ceweeman River. There would also be a significant amount of floodplain area crossed by the West Alternative and options in the Lacamas Creek valley upstream of Lacamas Lake. As a consequence, the West Alternative and options have the potential for the greatest amount of total floodplain area crossed, the greatest amount of vegetation clearing, the largest number of towers, and the most road construction (see Table 15). In contrast, the East, Central, and Crossover alternatives and options cross smaller streams with smaller floodplain areas, and thus have lower total impact values.

The degree of existing floodplain impairment is an important consideration when interpreting these results. Although the West Alternative and options have the highest total impact area values, these routes cross floodplains that are already greatly affected by existing agricultural and residential uses. These land uses have resulted in widespread clearing, road construction, ditching, filling, and grading within floodplain areas. For instance, although the total amount of floodplain clearing associated with the West Alternative and options ranges from 11 to 16 acres, up to 84-86% of these floodplain areas are already cleared, which suggests considerable existing impairment to floodplain processes. An even greater portion of these floodplains are further impacted by existing ditching and filling. The East, Central, and Crossover alternatives and options affect less floodplain area, and although these floodplains are generally less impaired, existing levels of clearing nevertheless range up to 67-83%.

Overall, due to the total extent of potential floodplain impacts, and given the degree of existing floodplain impairment, the potential for significant impairment of floodplain functions, including reach-scale flood inundation processes and channel migration rates, is expected to be low for all transmission line alternatives and options. This assessment should be viewed as an evaluation of the relative potential impact to floodplain function indicators. The total impact area values do not specifically quantify floodplain functions themselves. Further investigation of specific impacts and implications to stream geomorphic function and aquatic habitat will require field investigation and additional analysis of site-specific conditions.

## FISH IMPACT ASSESSMENT

This assessment uses production value of listed salmon and steelhead in streams as an index of the relative potential or risk of impact of alternative corridor routes on fish resources. While a variety of fish species occur in the region, listed salmon and steelhead are of particular concern and will be the focus of biological assessments required by their listing status. Fish production value is defined for the purposes of this analysis as a number of fish or percentage of the fish population. Any given stream might support none, some, or all of four listed salmon and steelhead species. Different stream reaches may also be more or less productive for any given species depending on prevalent habitat conditions and their suitability for different stages of a species' life cycle (a reach is a stream segment defined by similar physical characteristics).

Fish impact potential is related to: 1) the fish production value in the stream reach affected by the project and 2) the extent to which reductions in fish production may be realized as a result of direct and indirect project-related impacts on fish habitat or fish habitat forming processes. Generally-speaking, routes with more stream crossings of high-value fish streams will have a greater potential for impact and higher fish production potential than routes with fewer crossings of low-value fish streams. Similarly, routes with greater hydrological, floodplain, riparian, or sediment disturbance are more likely to result in substantial degradation of the fish production potential. Four indices related to fish impact potential were calculated:

1. Net fish production potential,
2. Population potential,
3. Population potential for priority populations identified for salmon recovery, and
4. Fish impact related to project effects on fish habitat.

The first three indices (production potential, population potential, ESU potential) describe the potential for fish impacts of each route alternative. Fish potential is expressed in terms of fish numbers (adult salmon), percentage of the population, and percentage of populations identified as a priority for salmon protection and restoration in Salmon Recovery Plans adopted by the State of Washington and the National Marine Fisheries Service. Fish numbers are estimated within the footprint of the right-of-way at each stream crossing for each of the four listed salmon species. Stream crossings are a convenient way to represent all project activities that might directly or indirectly affect fish habitat.

The fourth index (integrated impacts) describes the amount of fish potential that might be expected to be affected by fish habitat changes associated with the project. Where fish potential indices identify the numbers of fish available within the project area, the impact identifies how much of that potential might be lost due to project effects. The fourth (integrated impacts) index is intended to represent the net effects of transmission line construction and maintenance on watershed, riparian, and floodplain processes and functions that directly and indirectly affect fish habitat. This assessment integrates findings of the hydrology, sediment, riparian, and floodplain impact analyses in order to rate the loss of fish productivity associated with potential habitat impacts.

## **Methods**

### Data

Analyses were based on salmon and steelhead data from the Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan (LCFRB 2010b) which was adopted by the National Marine Fisheries Society as the Recovery Plan for this region. Distribution and abundance of listed salmonid species in southwest Washington streams was quantified on a reach-by-reach basis by the Washington Lower Columbia Fish Recovery Board and WDFW. These data were the basis for analyses of limiting factors, protection and restoration values, and recovery priorities established in the Salmon Recovery Plan. These data provide a systematic means of weighing the relative potential impact of different transmission routes in a quantitatively rigorous and transparent manner. Using the same data as the Recovery Plan has the added benefit of providing a clear description of potential take in ESA consultations for the transmission line project.

The LCFRB fish database describes fish numbers and the population contribution of each anadromous fish producing stream reach in southwest Washington (Table 16). Data were developed for all streams using the Ecosystem Diagnosis and Treatment (EDT) model. EDT is a mechanistic model that is based on the relationships between aquatic habitat characteristics and fish performance. The model estimates fish numbers from fish habitat quantity and quality (e.g. pools, hydrology, riparian conditions, sediment, water quality, and woody debris). Model inputs include descriptions of the physical stream environment, at a reach level, which are then related through a set of rules to life-stage specific survival. These survival characteristics are then integrated across the entire life history of the population. Results include estimates of population productivity, capacity, equilibrium abundance, and diversity. EDT is typically used to model conditions for the current (patient) and historical (template) scenarios.

Locations of crossings for each alternative transmission line segment were obtained from the stream crossings compiled as part of the Riparian Impact Assessment. Stream crossings were derived from the WaDNR database WCHYDRO from the Forest Practices Application Review System. This reference data set, used for all forest practices applications, represents fish-bearing streams at a 1:25,000 hydrography scale or finer as identified based on field surveys. Several data sets were initially reviewed to identify fish-bearing streams: WaDNR's water typing, WDFW fish distribution data, EDT (which was used in salmon recovery planning), and critical habitat data sets from the National Oceanic and Atmospheric Administration and United States Fish and Wildlife Service. Under current stream typing rules utilized by the WaDNR, "F" streams contain the extents of all other the other data sources and therefore were utilized as the basis for determining fish-bearing streams crossed by the proposed project alternatives and options.

Fish bearing streams can include anadromous and non-anadromous species. Many crossings of small, high-gradient streams might contain only resident species such as cutthroat trout. As a result, a number of crossings could occur on fish-bearing streams that were not represented in EDT analysis of current anadromous species distribution. However, due to the widespread distribution of listed salmon and steelhead species, it was assumed for the purposes of this

analysis that salmon and steelhead distribution is provides a representative index of relative project effects on fish species in general.<sup>1</sup>

**Table 16. Example of reach and species-specific fish production data available for southwest Washington streams in the LCFRB salmon recovery database.**

Subbasin	Reach	Length (meters)	Recovery Tier <sup>1</sup>	Fish /100 m	Production Rating <sup>2</sup>	Population Proportion <sup>3</sup>	Significance <sup>4</sup>	Potential (%) <sup>5</sup>
Ceweeman	Baird Cr 1 A	1921	1	0.4	VL	0.002	VL	0.86
Ceweeman	Baird Cr 1 B	2741	2	0.0	VL	0.000	VL	3.69
Ceweeman	Baird Cr 2	1448	2	0.0	VL	0.000	VL	0.00

<sup>1</sup>Recovery tier = salmon recovery priorities based on multi-species production values (ranked in tiers 1-4).

<sup>2</sup>Production rating is a ranking of the production value relative to nominal values for the species (high, medium, low, very low).

<sup>3</sup>Population portion is the reach contribution to the entire subbasin's production of a species.

<sup>4</sup>Significance is a ranking of the importance of the reach to the local population based on population proportion.

<sup>5</sup>Potential is the percentage of current production relative to the historical production value.

### Calculating the Fish Production Potential Index (F)

The Fish Production Potential index quantifies the potential impact of habitat degradation based on the estimated number of adult salmon produced in the area affected by transmission line crossings. This index value is calculated:

$$F_{sgc} = A_{spr} (T_{gc} / L_r)$$

where

$F_{sgc}$  = Fish number (average number of adults) produced for species 's' for transmission line segment 'g' and crossing 'c'.

$A_{spr}$  = Adults (average number) of species 's' and population 'p' produced in stream reach 'r'.

$T_{gc}$  = Length of stream affected by line segment 'g' and crossing 'c'.

$L_r$  = Length of reach 'r' (ft).

Length of affected stream was estimated based on the angle of line intersection with the stream and a transmission line corridor buffer width of approximately 150 ft.<sup>2</sup> Fish number per reach and reach length were obtained from the salmon recovery plan database as estimated from fish habitat using the EDT model. Based on the EDT fish values used in this application, the Fish Production Potential index can be defined as the average number of fish that would be affected if the crossing reduced habitat conditions at the crossing site by 100% of the current potential.

Fish Production Potential index values were calculated for each listed salmon species and race (coho, chum, fall Chinook, spring Chinook, winter steelhead). Each species consists of multiple

<sup>1</sup>Other fish species such as cutthroat trout may occur in smaller streams that are not utilized by salmon and steelhead but in general greater project impacts on salmon and steelhead may be assumed to be positively correlated to greater impacts on other fish species such as cutthroat trout.

<sup>2</sup>BPA provided a polygon GIS database of transmission line clearing. This database was laid over stream centerlines to determine the length of stream potentially affected. Crossings could be perpendicular, but many were oblique. Affected length values used in this exercise include areas of additional riparian clearing but not areas that were previously cleared for other purposes.

populations which might occur in one or more stream subbasins within the project area. Values were summed across species for a net index value for each crossing and across segments for a net value for each segment (Table 17). Similarly, values were summed for all segments in each route alternative or option.

**Table 17. Example calculation of the Fish Production Potential index for two transmission line segments (units are adults per affected stream length).**

Segment	Crossing	Chinook			Steelhead			Net
		Coho	Chum	Spring	Fall	Summer	Winter	
A	1	6.2	0.0	0.0	20.4	0.0	0.8	27.4
	2	1.6	0.0	0.0	5.5	0.0	3.5	10.6
	3	0.4	0.0	0.0	3.5	0.0	1.9	5.7
	Total	8.2	0.0	0.0	29.4	0.0	6.2	43.7
B	1	10.2	0.0	0.0	3.1	0.0	0.4	13.7
	2	2.8	0.0	0.0	0.8	0.0	1.7	5.3
	3	1.7	0.0	0.0	0.2	0.0	0.9	2.9
	Total	14.7	0.0	0.0	4.1	0.0	3.1	21.9

#### Calculating the Fish Population Potential Index (P)

The Fish Population Potential index quantifies the potential for impact of habitat degradation based on the estimated proportion of the local fish population produced in the area affected by transmission line crossings. This index is calculated in the same manner as the Fish Production Potential index, except that the fish production values are expressed in terms of the relative percentage of the population total, as opposed to numbers of fish:

$$P_{sgc} = (F_{sgc} / A_{sp.}) 100$$

where

$P_{sgc}$  = Percentage of fish population produced for species 's' for transmission line segment 'g' and crossing 'c'.

$F_{sgc}$  = Fish number (average number of adults) produced for species 's' for transmission line segment 'g' and crossing 'c'.

$A_{sp.}$  = Total adults (average number) of species 's' and population 'p' for all stream reaches combined.

Fish numbers per population were obtained from the salmon recovery plan database as estimated from fish habitat using the EDT model. Based on the EDT fish values used in this application, the Fish Population Potential index can be defined as the proportion of the population that would be affected if a crossing reduced habitat conditions at the crossing site by 100% of the current potential. This index can be thought of as a normalized value across populations so that comparisons can be made irrespective of population size.

Fish Population Potential index values are generated for each listed salmon species and race (coho, chum, fall Chinook, spring Chinook, winter steelhead). Each species consists of multiple populations which might occur in one or more stream subbasins within the project area. Values were summed within each population for each crossing or route (Table 18). Population totals

were averaged to provide a net index value for each crossing or route. The index thus represents the average percentage of the six potential listed fish populations affected.

**Table 18. Example calculation of the Fish Population Potential index for two transmission line segments (units are percentage of population in affected stream length).**

Segment	Crossing	Coho	Chum	Chinook		Steelhead		Index (avg.)
				Spring	Fall	Summer	Winter	
A	1	2.07	0.00	0.00	4.08	0.00	0.40	1.09
	2	0.53	0.00	0.00	1.10	0.00	1.75	0.56
	3	0.13	0.00	0.00	0.70	0.00	0.95	0.30
	Total	2.73	0.00	0.00	5.88	0.00	3.10	1.95
B	1	3.40	0.00	0.00	0.62	0.00	0.20	0.70
	2	0.93	0.00	0.00	0.16	0.00	0.85	0.32
	3	0.57	0.00	0.00	0.04	0.00	0.45	0.18
	Total	4.90	0.00	0.00	0.82	0.00	1.50	1.20

#### Calculating the Fish ESU Potential Index (E)

The Fish Evolutionarily Significant Unit (ESU) Potential index uses the Fish Population Potential index and “weights” it based on the importance of the populations present (at a crossing) to the regional ESA recovery strategy:

$$E_{sgc} = P_{sgc} W_p$$

where

$E_{sgc}$  = Percentage of fish population produced for species ‘s’ for transmission line segment ‘g’ and crossing ‘c’, weighted by population significance to salmon recovery.

$P_{sgc}$  = Percentage of fish population produced for species ‘s’ for transmission line segment ‘g’ and crossing ‘c’.

$W_p$  = Population weight based on recovery plan priority (1.0 for primary populations, 0.5 for contributing populations, 0.0 for stabilizing populations).

The Salmon and Steelhead Recovery Plan recognizes that not every salmon population can be restored to high levels and targets different populations for different levels of improvement (see Table 19 for recovery objectives in the affected project area). Populations are categorized in decreasing level of significance as primary, contributing, or stabilizing (LCFRB 2010b):

*Primary populations* are targeted for restoration to high or very high viability. These populations are the foundation of salmon recovery. Primary populations are typically the strongest extant populations and/or those with the best prospects for protection or restoration.

*Contributing populations* are those for which some improvement will be needed to achieve a stratum-wide average of medium viability. Contributing populations might include those

of low to medium significance and viability where improvements can be expected to contribute to recovery.

*Stabilizing populations* are those that would be maintained at baseline levels. These are typically populations at very low viability during the listing baseline. Stabilizing populations might include those where significance is low, feasibility is low, and uncertainty is high.

The Fish ESU Potential index reflects both the relative significance of the affected stream area to the population and the relative importance of the population to the listed species. As such, the index is the most effective of the three fish indices for describing the relative significance of project effects to ESA-listed salmon and steelhead. The production and population indices provide supporting detail for the components of the ESU-scale index.

**Table 19. Recovery objectives for lower Columbia salmon and steelhead populations affected by the action alternatives and options (LCFRB 2010b). Viability levels: Primary (P), Contributing (C), and Stabilizing (S).**

	Chinook			Chum		Steelhead		Coho
	Fall	Late Fall	Spr.	Fall	Sum.	Win.	Sum.	
Lower Cowlitz	C	--	--	C	C	C	--	P
Coweeman	P	--	--			P	--	P
Kalama	C	--	C	C	--	P	P	C
NF Lewis	P	P	P	P	--	C	S	C
EF Lewis		--	--		--	P	P	P
Salmon	S	--	--	S	--	S	--	S
Washougal	P	--	--	P	--	C	P	C

#### Calculating the Integrated Fish Impact Index (I)

The Integrated Fish Impact index is a product of the Fish ESU Potential index and the estimated reduction in stream habitat conditions for fish associated with project-related activities:

$$I_{sgc} = E_{sgc} (C_{gc} R_{gc})$$

where

$I_{sgc}$  = Proportional reduction in fish population associated with riparian habitat function alterations for species 's' for transmission line segment 'g' and crossing 'c', weighted by population significance to salmon recovery.

$E_{sgc}$  = Proportion of fish population produced for species 's' for transmission line segment 'g' and crossing 'c', weighted by population significance to salmon recovery.

$C_{gc}$  = Proportion of the length of stream affected by line segment 'g' and crossing 'c' ( $T_{gc}$ ), subject to project-related clearing of riparian vegetation.

$R_{gc}$  = Proportional reduction in riparian function due to clearing of riparian vegetation by line segment 'g' and crossing 'c'.

The Integrated Fish Impact index describes a proportional reduction in fish production at the population scale based on the Riparian Impact Assessment. Riparian impacts were expressed as a product of the length of stream within the right-of-way footprint where clearing occurred,

scaled by the near-term riparian function at the crossing. For crossings with high riparian function ratings (high LWD recruitment potential and low stream shade hazard), we applied a scalar of 1.0. Non-forested crossings were scaled by 0.0; crossings with moderate riparian function were scaled by 0.67; and, crossings with low function were scaled by 0.33. In this way, greater reductions in fish numbers would occur along streams with the greatest potential loss in habitat; no losses would occur along streams with no potential loss in riparian habitat function. Thus, greater loss of habitat and fish production potential would be associated with substantial clearing of high-function riparian habitat. Lesser loss of habitat and fish production potential would be associated with clearing of low-functioning riparian habitat (for instance, in cases where riparian vegetation has already been substantially degraded or removed).

Of the four habitat effects, only loss of riparian function would have measurable and potentially significant effects at the stream crossing scale (due to loss of large woody debris and stream shade). In comparison, sediment, hydrology, and floodplain effects would be relatively minor or indeterminate, or dispersed over a much broader area. Therefore, the Integrated Fish Impact index incorporated only potential impacts from loss of riparian function.

## **Results**

### Stream Crossing Inventory

Alternatives and options cross a total of 254 fish bearing streams. Of these, about 40% produce anadromous fish (Table 20). The balance support only resident species such as cutthroat trout. Numbers of fish-bearing stream crossings vary among the alternatives and options from 54 to 82. Similar differences are apparent in numbers of anadromous crossing. Tables and maps with more information on stream crossings may be found in the Appendix D.

**Table 20. Number of stream crossings for action alternatives and options (sorted by increasing number for fish bearing streams).**

Alternative	Fish bearing	Anadromous
East Option 1	54	25
East Alternative	59	24
East Option 3	63	23
Central Option 3	66	27
East Option 2	66	21
Central Option 2	69	30
West Alternative	71	39
West Option 2	72	40
West Option 1	73	39
Central Alternative	74	29
Crossover Alternative	75	32
Central Option 1	76	30
West Option 3	79	43
Crossover Option 2	80	35
Crossover Option 3	80	34
Crossover Option 1	82	33
<b>All</b>	<b>254</b>	<b>104</b>

### Fish Production Potential Index

The Fish Production Potential index estimates the number of adult salmon or steelhead produced in the area affected by each transmission line crossing, all crossings in a route segment, and all segments in an action alternative or option. This index describes the maximum number of fish that might be affected by project-related changes in stream habitat conditions within the right-of-way footprint. Actual project impact on fish production will depend on the degree of habitat degradation (as reflected by the Integrated Fish Impact index).

Table 21 summarizes fish production values by species and totals for all species for the action alternatives and options. Fish production values varied substantially among all options at the extremes, although differences among many actions were relatively minor. Values were lowest for the East Alternative and options and greatest for the West Alternative and options.

Fish Production Potential index values were driven by the number of stream crossings and the significance of associated stream segments to different species. Large numbers of crossings increased the potential for fish effects. Based strictly on a fish number basis, some species such as chum and fall Chinook salmon would tend to be more greatly affected than others such as coho steelhead due to differences in fish densities in affected areas related to species life-history. The production potential of chum and fall Chinook salmon is relatively large in the larger, lower-elevation mainstem areas where this species concentrates for spawning. In contrast, coho and steelhead are widely distributed throughout a subbasin and typically occur at relative lower numbers in any given stream segment.

**Table 21. Fish Production Potential index values for action alternatives and options (number of adult fish produced in affected stream sections, by species). Values are sorted by increasing index score.**

Alternative	Coho	Chum	Chinook		Steelhead		Index (Total)
			Fall	Spring	Winter	Summer	
East Option 3	2.3	13.4	7.7	0.3	0.7	1.1	25.6
East Option 2	2.4	13.4	7.7	0.3	4.1	0.5	28.6
East Alternative	2.6	13.4	7.7	0.3	4.8	1.1	30.1
East Option 1	6.2	16.5	8.4	0.3	4.8	1.1	37.3
Central Alternative	3.4	13.8	36.3	9.6	5.9	0.4	69.4
Central Option 1	3.4	13.8	36.3	9.6	5.9	0.4	69.5
Central Option 2	2.9	13.8	37.1	9.6	5.8	0.4	69.6
Central Option 3	5.4	13.8	37.0	9.8	5.4	0.3	71.8
Crossover Alternative	5.7	25.0	41.2	9.5	6.1	0.8	88.4
Crossover Option 2	6.5	25.0	41.2	9.5	6.2	0.8	89.2
Crossover Option 3	8.2	25.0	41.2	9.5	6.2	0.8	90.9
Crossover Option 1	5.7	25.0	41.2	9.5	13.1	0.9	95.4
West Option 2	12.0	39.0	48.2	6.0	2.7	0.1	107.9
West Alternative	12.0	39.0	48.2	6.0	8.1	0.1	113.3
West Option 1	12.0	39.0	48.2	6.0	8.1	0.1	113.3
West Option 3	12.9	43.1	50.8	6.0	3.6	0.1	116.5

### Fish Population Potential Index

The Fish Population Potential index estimates the proportion of the adult fish population produced in the area affected by each transmission line crossing, all crossings in a route segment, and all segments in an action alternative or option. Expressing fish indices in terms of population percentages rather than actual numbers somewhat dampened the disproportionate effects of some species related to life history differences. This index describes the maximum population percentage that might be affected by project-related changes in stream habitat conditions within the right-of-way footprint. Actual project impact will depend on the degree of habitat degradation (as reflected by the Integrated Fish Impact index).

Table 22 summarizes fish population values by species and averages for all species for a number of action alternatives and options. Fish population values varied among all options at the extremes, although differences among many actions were relatively minor. Values were generally lowest for the East Alternative and options and greatest for the Crossover and West alternatives and options (although there were exceptions to this pattern).

Fish Population Potential index values suggest that the scale of action effects would be quite low for all alternatives (based on the simplistic assumption that maximum effects would be equivalent to the fish production in the corridor alteration footprint as measured by stream length). Index values are 1% or less for most species and most options, but values up to 2.45% were estimated for chum salmon due to several crossings occurring in relatively high-value chum salmon habitat which is extremely limited. The combination of a large number of stream crossings and crossings in stream reaches utilized by multiple species tended to drive action alternatives or options with the highest potential for fish impact at a population scale.

**Table 22. Fish Population Potential index values for action alternatives and options (percentage of population produced in affected stream sections, by species). Values are sorted by increasing index score.**

Alternative	Chinook				Steelhead		Index (Avg.)
	Coho	Chum	Spring	Fall	Winter	Summer	
East Option 3	0.20	1.86	0.40	0.09	0.17	0.44	0.53
East Option 2	0.23	1.86	0.40	0.09	0.97	0.14	0.62
East Alternative	0.28	1.86	0.40	0.09	1.17	0.44	0.71
East Option 1	0.28	1.91	0.45	0.09	1.16	0.44	0.72
West Option 2	0.84	1.86	0.91	0.27	0.72	0.02	0.77
Central Option 2	0.21	1.87	0.58	0.44	1.42	0.12	0.77
Central Alternative	0.29	1.87	0.53	0.44	1.44	0.12	0.78
Central Option 1	0.29	1.87	0.53	0.44	1.45	0.12	0.78
Central Option 3	0.39	1.87	0.54	0.45	1.38	0.08	0.78
Crossover Alternative	0.38	2.04	0.79	0.42	1.54	0.39	0.93
Crossover Option 2	0.39	2.04	0.79	0.42	1.55	0.39	0.93
Crossover Option 3	0.43	2.04	0.79	0.42	1.55	0.39	0.94
West Option 3	1.03	2.45	1.06	0.27	0.96	0.02	0.96
West Alternative	0.84	1.86	0.91	0.27	2.05	0.02	0.99
West Option 1	0.84	1.86	0.91	0.27	2.05	0.02	0.99
Crossover Option 1	0.38	2.04	0.79	0.42	3.25	0.40	1.21

### Fish ESU Potential Index

The Fish ESU Potential index estimates a weighted proportion of the adult fish population produced in the area potentially affected by each action alternative or option. Weights based on population priorities identified in the lower Columbia River salmon recovery plan tend to reduce the average potential index values for populations which are not targeted for high levels of protection or restoration. This index describes the maximum percentage of priority fish populations that might be affected by project-related changes in stream habitat conditions. Actual project impact will depend on the degree of habitat degradation (as reflected by the Integrated Fish Impact index).

Table 23 summarizes Fish ESU Potential index values by species and weighted averages for all species for the action alternatives and options. Fish population values varied among all options at the extremes although differences among many actions were relatively minor. Just 0.4% of the average population separates all alternatives. Values were generally lowest for the East alternative and options, and greatest for the Crossover and West alternatives and options (although there were exceptions to this pattern).

Index values suggest that the scale of action effect would be quite low for all alternatives (based on the simplistic assumption that maximum effects would be equivalent to the fish production in the corridor alteration footprint as measured by stream length). Index values are 1% or less for most species and most options, but values up to 1.95% were estimated for chum salmon due to several crossings occurring in relatively high-value chum salmon habitat which is extremely limited. A combination of multi-species production potential and a large number of stream crossings associated with an alternative or option tend to drive action alternatives or options towards higher levels of potential for fish impact.

**Table 23. Fish ESU Potential index values for action alternatives and options (percentage of population produced in affected stream sections, by species, weighted by population priority for recovery). Values are sorted by increasing index score.**

Alternative	Chinook					Steelhead		Index (avg.)
	Coho	Chum	Spring	Fall	Winter	Summer		
East Option 3	0.17	1.86	0.40	0.05	0.15	0.44	0.51	
East Option 2	0.18	1.86	0.40	0.05	0.64	0.14	0.54	
East Alternative	0.20	1.86	0.40	0.05	0.65	0.44	0.60	
East Option 1	0.22	1.88	0.45	0.05	0.65	0.44	0.61	
West Option 2	0.64	1.77	0.69	0.05	0.55	0.02	0.62	
Central Option 3	0.27	1.87	0.53	0.07	0.95	0.08	0.63	
Central Option 2	0.15	1.86	0.58	0.07	1.06	0.12	0.64	
Central Alternative	0.22	1.87	0.53	0.07	1.06	0.12	0.64	
Central Option 1	0.22	1.87	0.53	0.07	1.06	0.12	0.64	
West Alternative	0.64	1.77	0.69	0.05	1.21	0.02	0.73	
West Option 1	0.64	1.77	0.69	0.05	1.21	0.02	0.73	
Crossover Alternative	0.31	1.95	0.79	0.05	0.98	0.39	0.75	
Crossover Option 2	0.32	1.95	0.79	0.05	0.99	0.39	0.75	
Crossover Option 3	0.36	1.95	0.79	0.05	0.99	0.39	0.76	
West Option 3	0.73	2.36	0.84	0.05	0.66	0.02	0.78	
Crossover Option 1	0.31	1.95	0.79	0.05	1.84	0.40	0.89	

### Integrated Fish Impact Index

The Integrated Fish Impact index estimates the proportional reduction in fish numbers associated with project-related habitat degradation at the crossing scale. Units of this index are expressed as the average percentage of high priority populations for all listed salmon and steelhead species. While the fish potential indices described the maximum numbers that might be affected, the Integrated Fish Impact index identifies the percentage by which affected populations are likely to be reduced by project-related habitat changes.

Table 24 summarizes Integrated Fish Impact index values by species and averages for all species for a number of action alternatives and options. Fish population values varied among all options at the extremes although differences among many actions were relatively minor. Just 0.16% of the average population index value separates all alternatives and options. Values were generally lowest for the West Alternative and options, intermediate for the Central Alternative and options and greatest for the Crossover Alternative and options. Values for the East Alternative and options ranked from relatively low to relatively high.

Index values suggest that the scale of action effects would be quite low for all alternatives. Index effects are 0.21% or less for all options where averaged for all species, but values up to 0.73% were estimated for winter steelhead due to several crossings occurring in relatively high-value streams with highly functional habitat that will require substantial clearing.

**Table 24. Integrated Fish Impact index values for action alternatives and options (percentage reduction in priority fish populations due to project-related habitat effects). Values are sorted by increasing index score.**

Alternative	Coho	Chum	<u>Chinook</u>		<u>Steelhead</u>		Index (avg.)
			Spring	Fall	Winter	Summer	
West Option 2	0.077	0.149	0.097	0.018	0.139	0.005	0.081
East Option 3	0.084	0.000	0.047	0.031	0.077	0.293	0.089
West Option 3	0.104	0.149	0.097	0.018	0.161	0.005	0.089
East Option 2	0.084	0.000	0.047	0.031	0.298	0.089	0.091
West Alternative	0.077	0.149	0.097	0.018	0.294	0.006	0.107
West Option 1	0.077	0.149	0.097	0.018	0.294	0.006	0.107
Central Option 3	0.127	0.003	0.092	0.022	0.412	0.025	0.113
Central Option 2	0.073	0.006	0.154	0.022	0.517	0.064	0.139
Central Alternative	0.118	0.006	0.136	0.022	0.530	0.064	0.146
Central Option 1	0.118	0.006	0.136	0.022	0.530	0.064	0.146
East Option 1	0.110	0.007	0.064	0.031	0.636	0.293	0.190
East Alternative	0.125	0.000	0.047	0.031	0.648	0.293	0.191
Crossover Alternative	0.076	0.016	0.128	0.018	0.729	0.258	0.204
Crossover Option 2	0.081	0.016	0.128	0.018	0.729	0.258	0.205
Crossover Option 3	0.093	0.016	0.128	0.018	0.730	0.258	0.207
Crossover Option 1	0.076	0.016	0.128	0.018	0.948	0.259	0.241

## ***Discussion***

Fish indices provide a systematic means for comparing relative differences in potential for project impact among the various corridor routes and alternatives. Index values are related to the number of stream crossings, lengths of affected stream, the significance of fish production in affected stream reaches, the priority of fish populations for salmon recovery, and the effects of project activities in proximity to stream crossings on fish habitat conditions.

The Integrated Fish Impact index reflects the relative significance of the affected stream area to priority-listed fish populations and the reduction in fish production associated with project activities in proximity to stream crossings. As such, the integrated index is the most effective of the fish indices for describing project effects on ESA-listed salmon and steelhead.

Rank order varied somewhat among the four indices as a result of differences in fish production value, stream reach significance to populations of each species, population priority for recovery, and the scale of habitat impact on fish production potential. Groupings in Table 25 denote alternatives and options with similar Integrated Fish Impact index values.

*West Alternative and options* rank among the lowest in terms of fish impacts based on the Integrated Fish Impact index. Fish production potential was generally higher because routes included a high number of crossings and many of these occurred at relatively high-value streams for anadromous species. However, project-related habitat effects were relatively low in comparison with other routes because many stream crossing occurred at locations where conditions in the right-of-way were already altered. Hence, these routes generally required much less clearing of highly-functioning riparian vegetation. Differences among the alternatives and options were driven by variations in the Washougal basin east of Vancouver.

*Crossover Alternative and options* generally ranked highest due to both high fish production potential and greater loss of highly-functioning riparian vegetation. These routes crossed a high number of anadromous fish-bearing streams, including many low to intermediate elevation streams which produced more fish and more species of fish on a per unit length basis. Affected populations were more frequently identified in the salmon recovery plan as high priorities for habitat protection or restoration. More riparian zones in these areas required significant clearing and riparian zones were more likely to have highly-functional riparian vegetation. Hence, reductions in fish production potential would be more likely to be greater.

*Central Alternative and options* were generally intermediate between East and Crossover alternative routes in terms of fish impact based on the integrated index. The number of crossings of anadromous fish bearing streams was intermediate as was the fish production value of these crossings. The magnitude of riparian clearing and functional quality of riparian zones was intermediate as well.

*East Alternative and options* ranked from low to moderately high based on the Integrated Fish Impact index. Fish production potential was relatively low because the number of crossings of anadromous streams would be lower than other alternatives and these routes would generally cross smaller, higher elevation streams inhabited at relatively low densities by a limited number of species (typically steelhead and coho). However, many of these crossings would require substantial clearing of relatively high-functioning riparian vegetation.

**Table 25. Relative ranks of alternatives and options based on fish production, population and ESU indices (sorted by Integrated Fish Impact index in order of increasing index value – higher rank numbers denote lower impacts).**

	Fish Potential						Riparian impact (%) <sup>1</sup>	Integrated impact			
	Production		Population		ESU			Index	Rank	Group	
	Fish no.	Rank	Index	Rank	Avg. %	Rank					
West Option 2	107.9	4	0.77	12	0.62	12	13%	0.08	16	A	
East Option 3	25.6	16	0.53	16	0.51	16	17%	0.09	15	A	
West Option 3	116.5	1	0.96	4	0.78	2	11%	0.09	14	A	
East Option 2	28.6	15	0.62	15	0.54	15	17%	0.09	13	A	
West Alternative	113.3	3	0.99	3	0.73	7	15%	0.11	12	A	
West Option 1	113.3	2	0.99	2	0.73	6	15%	0.11	11	A	
Central Option 3	71.8	9	0.78	8	0.63	11	18%	0.11	10	A	
Central Option 2	69.6	10	0.77	11	0.64	10	22%	0.14	9	B	
Central Alternative	69.4	12	0.78	10	0.64	9	23%	0.15	8	B	
Central Option 1	69.5	11	0.78	9	0.64	8	23%	0.15	7	B	
East Option 1	37.3	13	0.72	13	0.61	13	31%	0.19	6	C	
East Alternative	30.1	14	0.71	14	0.60	14	32%	0.19	5	C	
Crossover Alternative	88.4	8	0.93	7	0.75	5	27%	0.20	4	C	
Crossover Option 2	89.2	7	0.93	6	0.75	4	27%	0.21	3	C	
Crossover Option 3	90.9	6	0.94	5	0.76	3	27%	0.21	2	C	
Crossover Option 1	95.4	5	1.21	1	0.89	1	27%	0.24	1	D	

<sup>1</sup>Percentage of fish production in right-of-way footprint of stream crossings impacted by project-related riparian habitat effects. (This differs from simple riparian index values due to the crossing-specific significance of fish production.)

None of the alternatives and options appear to pose a substantial risk to listed species. Fish indices suggest that the net effect of any project route on anadromous fish populations will be on the order of 1% even with the most pessimistic assumptions for impact at stream crossings (e.g., fish production potential is degraded to zero and no effective mitigation occurs). Habitat impact indices suggest that only a fraction of the potential fish production is likely to be lost due to project effects.

Relative differences identified among the alternatives appear to be quite small when considered on an absolute scale. While small relative differences might be identified among the various alternatives, these differences are practically negligible such that most options within an alternative are effectively interchangeable from a listed fish species point of view.

This is not to downplay the significance of the project when considered in aggregate with all of the other habitat and non-habitat related factors which have contributed to depletion and listing of these populations. Any given factor may contribute only a small impact but the combined effect of many small impacts has often proven to be substantial. It is also noteworthy that any additional impacts will further degrade the status of these listed species from current levels. Degradation of habitat conditions in high-priority fish populations and stream reaches is also contrary to objectives and strategies identified in the salmon and steelhead recovery plan.

Ultimately, fish index values are most robust as relative indices of differences in fish production potential or impact among the various route alternatives. Index values are likely to be correlated with actual values but may or may not precisely quantify the actual reduction in fish production that will result due to the project. Index values were defined to the extent possible in terms of meaningful units of effect so that these impacts might be placed in context with other considerations, such as wetlands or wildlife effects of the proposed project. However, these units should be considered with caution. Actual impacts might be more or less than the estimated fish production within the footprint of a stream crossing area. Project actions might impact a larger portion of the stream than just the footprint at each crossing. For instance, hydrology, sediment, and floodplain impacts, although small, may affect a relatively large portion of the watershed downstream. Similarly, riparian impacts can affect conditions both at the site of alteration and for a substantial distance downstream. On the other hand, project effects at each crossing may not be so severe as to degrade fish production in affected reaches to the degree reflected in the index. However, index values continue to robust indicators of relative difference among alternatives because values will consistently underestimate or overestimate actual impacts for all alternatives.

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## APPENDIX A – STREAM HYDROLOGY ASSESSMENT DATA

Two lookup tables were developed for LANDFIRE vegetation types found within the subwatersheds crossed by the transmission line routes. One table was created for EVT and the second table for EVC. The EVT lookup table (Table A-1) was used to distinguish forested and non-forested cover vegetation types (CFS\_Forested = Yes/No). Within the forested vegetation types, EVT was further classified into conifer and hardwood forest cover (CFS\_SubCoverType = Conifer/Hardwood). The EVC lookup table (Table A-2) was used to distinguish the watershed analysis hydrologic maturity classification of conifer (CFS\_C\_CLASS) cover types. Hardwood and non-forested cover types are treated as being hydrologically immature.

**Table A-1. EVT lookup table for distinguishing forested and non-forested cover types (CFS\_Forested) and conifer and hardwood cover types (CFS\_SubCoverType).**

EVT_VALUE	EVT_Name	SystmGrpPh	NVCSOrder	CFS_Forested	CFS_SubCoverType
82	Agriculture-Cultivated Crops and Irrigated Agriculture	Agricultural	Herbaceous / Nonvascular-dominated	No	N/A
81	Agriculture-Pasture and Hay	Agricultural	Herbaceous / Nonvascular-dominated	No	N/A
63	NASS-Row Crop-Close Grown Crop	Agricultural	Herbaceous / Nonvascular-dominated	No	N/A
65	NASS-Close Grown Crop	Agricultural	Herbaceous / Nonvascular-dominated	No	N/A
66	NASS-Fallow/Idle Cropland	Agricultural	Herbaceous / Nonvascular-dominated	No	N/A
67	NASS-Pasture and Hayland	Agricultural	Herbaceous / Nonvascular-dominated	No	N/A
64	NASS-Row Crop	Agricultural	Herbaceous / Nonvascular-dominated	No	N/A
60	NASS-Orchard	Agricultural	Tree-dominated	No	N/A
2182	Introduced Upland Vegetation-Perennial Grassland and Forbland	Exotic Herbaceous	Herbaceous / Nonvascular-dominated	No	N/A
11	Open Water	Non-vegetated	Non-vegetated	No	N/A
32	Quarries-Strip Mines-Gravel Pits	Developed	Non-vegetated	No	N/A
140	Northern Rocky Mountain Subalpine-Upper Montane Grassland	Grassland	Herbaceous / Nonvascular-dominated	No	N/A
75	Herbaceous Semi-dry	Grassland	Herbaceous /	No	N/A

EVT_VALUE	EVT_Name	SystmGrpPh	NVCSOrder	CFS_Forested	CFS_SubCoverType
			Nonvascular-dominated		
76	Herbaceous Semi-wet	Grassland	Herbaceous / Nonvascular-dominated	No	N/A
95	Herbaceous Wetlands	Grassland	Herbaceous / Nonvascular-dominated	No	N/A
2139	Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	Grassland	Herbaceous / Nonvascular-dominated	No	N/A
2171	North Pacific Alpine and Subalpine Dry Grassland	Grassland	Herbaceous / Nonvascular-dominated	No	N/A
31	Barren	Non-vegetated	Non-vegetated	No	N/A
2186	Introduced Upland Vegetation-Shrub	Shrubland	Shrub-dominated	No	N/A
2083	North Pacific Avalanche Chute Shrubland	Shrubland	Shrub-dominated	No	N/A
2084	North Pacific Montane Shrubland	Shrubland	Shrub-dominated	No	N/A
2003	North Pacific Sparsely Vegetated Systems	Sparsely Vegetated	No Dominant Lifeform	No	N/A
16	Developed-Upland Herbaceous	Developed	Herbaceous / Nonvascular-dominated	No	N/A
24	Developed-High Intensity	Developed	No Dominant Lifeform	No	N/A
25	Developed-Roads	Developed	No Dominant Lifeform	No	N/A
23	Developed-Medium Intensity	Developed	No Dominant Lifeform	No	N/A
17	Developed-Upland Shrubland	Developed	Shrub-dominated	No	N/A
13	Developed-Upland Deciduous Forest	Developed	Tree-dominated	No	N/A
15	Developed-Upland Mixed Forest	Developed	Tree-dominated	No	N/A
14	Developed-Upland Evergreen Forest	Developed	Tree-dominated	No	N/A
2039	North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest	Conifer	Tree-dominated	Yes	Conifer
2018	East Cascades Mesic Montane Mixed-Conifer Forest and Woodland	Conifer	Tree-dominated	Yes	Conifer
2035	North Pacific Dry Douglas-fir(-Madrone) Forest and Woodland	Conifer	Tree-dominated	Yes	Conifer

EVT_VALUE	EVT_Name	SystmGrpPh	NVCSOrder	CFS_Forested	CFS_SubCoverType
2174	North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest	Conifer	Tree-dominated	Yes	Conifer
2036	North Pacific Hypermaritime Seasonal Sitka Spruce Forest	Conifer	Tree-dominated	Yes	Conifer
2178	North Pacific Hypermaritime Western Red-cedar-Western Hemlock Forest	Conifer	Tree-dominated	Yes	Conifer
2038	North Pacific Maritime Mesic Subalpine Parkland	Conifer	Tree-dominated	Yes	Conifer
2046	Northern Rocky Mountain Subalpine Woodland and Parkland	Conifer	Tree-dominated	Yes	Conifer
2037	North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest	Conifer	Tree-dominated	Yes	Conifer
2206	Pseudotsuga menziesii Giant Forest Alliance	Conifer	Tree-dominated	Yes	Conifer
2042	North Pacific Mesic Western Hemlock-Silver Fir Forest	Conifer	Tree-dominated	Yes	Conifer
2053	Northern Rocky Mountain Ponderosa Pine Woodland and Savanna	Conifer	Tree-dominated	Yes	Conifer
2045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	Conifer	Tree-dominated	Yes	Conifer
2173	North Pacific Wooded Volcanic Flowage	Conifer	Tree-dominated	Yes	Conifer
2157	North Pacific Swamp Systems	Conifer	Tree-dominated	Yes	Conifer
2041	North Pacific Mountain Hemlock Forest	Conifer	Tree-dominated	Yes	Conifer
2056	Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	Conifer	Tree-dominated	Yes	Conifer
2200	Pseudotsuga menziesii-Quercus garryana Woodland Alliance	Conifer-Hardwood	Tree-dominated	Yes	Conifer
2063	North Pacific Broadleaf Landslide Forest and Shrubland	Hardwood	Tree-dominated	Yes	Hardwood
2156	North Pacific Lowland Riparian Forest and Shrubland	Hardwood	Tree-dominated	Yes	Hardwood
2008	North Pacific Oak Woodland	Hardwood	Tree-dominated	Yes	Hardwood
2011	Rocky Mountain Aspen Forest and Woodland	Hardwood	Tree-dominated	Yes	Hardwood
2158	North Pacific Montane Riparian Woodland and Shrubland	Riparian	Tree-dominated	Yes	N/A

**Table A-2. EVT lookup table for hydrologic maturity of conifer cover types (CFS\_C\_CLASS); hardwood and non-forest cover types are assumed to be hydrologically immature.**

EVC_VALUE	CLASSNAMES	CFS_C_CLASS
100	Sparse Vegetation Canopy	Immature
101	Tree Cover >= 10 and < 20%	Intermediate
102	Tree Cover >= 20 and < 30%	Intermediate
103	Tree Cover >= 30 and < 40%	Intermediate
104	Tree Cover >= 40 and < 50%	Intermediate
105	Tree Cover >= 50 and < 60%	Intermediate
106	Tree Cover >= 60 and < 70%	Intermediate
107	Tree Cover >= 70 and < 80%	Mature
108	Tree Cover >= 80 and < 90%	Mature
109	Tree Cover >= 90 and <= 100%	Mature

**Table A-3. List of Subwatersheds Crossed by the Transmission Line Routes**

Central Alternative and Alternative Options

Subwatershed ID	Central Alternative			Central Option 1			Central Option 2			Central Option 3		
	Crossed?	Pre-Project Immature (ac)	Post-Project Immature (ac)	Crossed?	Pre-Project Immature (ac)	Post-Project Immature (ac)	Crossed?	Pre-Project Immature (ac)	Post-Project Immature (ac)	Crossed?	Pre-Project Immature (ac)	Post-Project Immature (ac)
17080001060304	No	0	0	No	0	0	No	0	0	No	0	0
17080001060501	Yes	3,792	3,793	Yes	3,792	3,793	Yes	3,792	3,793	Yes	3,792	3,793
17080001060502	Yes	5,207	5,226	Yes	5,207	5,226	Yes	5,207	5,226	Yes	5,207	5,226
17080001060503	Yes	1,724	1,749	Yes	1,724	1,749	Yes	1,724	1,749	Yes	1,724	1,749
17080001060504	Yes	6,903	6,907	Yes	6,903	6,907	Yes	6,903	6,907	Yes	6,903	6,907
17080001060506	Yes	1,484	1,486	Yes	1,484	1,486	Yes	1,484	1,486	Yes	1,484	1,486
17080001060601	Yes	3,767	3,768	Yes	3,767	3,768	Yes	3,767	3,768	Yes	3,767	3,768
17080001060602	Yes	5,798	5,798	Yes	5,798	5,798	Yes	5,798	5,798	Yes	5,798	5,798
17080001060603	No	0	0	No	0	0	No	0	0	No	0	0
17080001060605	Yes	3,858	3,908	Yes	3,858	3,908	Yes	3,858	3,908	Yes	3,858	3,908
17080001060606	No	0	0	No	0	0	No	0	0	No	0	0
17080001090106	No	0	0	No	0	0	No	0	0	No	0	0
17080001090109	Yes	3,933	3,986	Yes	3,933	3,986	Yes	3,933	3,986	Yes	3,933	3,986
17080001090110	No	0	0	No	0	0	No	0	0	No	0	0
17080001090112	No	0	0	No	0	0	No	0	0	Yes	3,472	3,487
17080001090115	No	0	0	No	0	0	No	0	0	No	0	0
17080001090116	No	0	0	No	0	0	No	0	0	No	0	0
17080001090117	No	0	0	No	0	0	No	0	0	No	0	0
17080001090118	No	0	0	No	0	0	No	0	0	No	0	0
17080001090119	No	0	0	No	0	0	No	0	0	No	0	0
17080001090126	No	0	0	No	0	0	No	0	0	No	0	0
17080001090128	No	0	0	No	0	0	No	0	0	No	0	0
17080001090134	No	0	0	No	0	0	No	0	0	No	0	0
17080002040502	No	0	0	No	0	0	No	0	0	No	0	0
17080002040505	No	0	0	No	0	0	No	0	0	No	0	0
17080002050401	Yes	3,206	3,249	Yes	3,206	3,249	Yes	3,206	3,249	Yes	3,206	3,237
17080002050403	No	0	0	No	0	0	No	0	0	No	0	0
17080002050405	No	0	0	No	0	0	No	0	0	No	0	0

17080002050501	No	0	0	No	0	0	No	0	0	Yes	1,581	1,582
17080002050502	Yes	2,259	2,265	Yes	2,259	2,265	Yes	2,259	2,265	Yes	2,259	2,279
17080002050503	No	0	0									
17080002050504	Yes	1,690	1,706	Yes	1,690	1,706	Yes	1,690	1,706	No	0	0
17080002050505	Yes	4,206	4,213	Yes	4,206	4,213	Yes	4,206	4,213	Yes	4,206	4,214
17080002050506	Yes	854	861	Yes	854	861	Yes	854	861	No	0	0
17080002050508	No	0	0									
17080002050509	No	0	0									
17080002050603	No	0	0									
17080002050604	No	0	0									
17080002050605	No	0	0	No	0	0	No	0	0	Yes	7,526	7,533
17080002050607	No	0	0									
17080002050608	No	0	0									
17080002050611	No	0	0									
17080002050612	No	0	0									
17080002050613	No	0	0									
17080002050615	No	0	0									
17080002060201	No	0	0									
17080002060203	No	0	0									
17080002060204	No	0	0									
17080002060302	No	0	0									
17080002060303	Yes	3,784	3,784	Yes	3,784	3,784	Yes	3,784	3,784	No	0	0
17080002060304	Yes	2,736	2,737	Yes	2,736	2,737	Yes	2,736	2,737	No	0	0
17080002060305	No	0	0									
17080002060402	No	0	0	No	0	0	No	0	0	Yes	3,298	3,307
17080002060403	Yes	2,006	2,025	Yes	2,006	2,025	Yes	2,006	2,025	Yes	2,006	2,008
17080002060404	Yes	6,759	6,787	Yes	6,759	6,787	Yes	6,759	6,787	Yes	6,759	6,761
17080002060405	Yes	5,288	5,307	Yes	5,288	5,307	Yes	5,288	5,307	No	0	0
17080002060406	Yes	6,260	6,282	Yes	6,260	6,282	Yes	6,260	6,282	No	0	0
17080002060502	No	0	0									
17080002060503	Yes	5,293	5,302									
17080002060504	Yes	2,697	2,706	Yes	2,697	2,706	Yes	2,697	2,706	Yes	2,697	2,703
17080003040302	No	0	0									
17080003040303	No	0	0									
17080003040401	Yes	2,976	3,037									
17080003040402	No	0	0									

17080003040403	No	0	0									
17080003040502	No	0	0									
17080003040503	Yes	3,010	3,032									
17080003040504	No	0	0									
17080003040505	Yes	4,010	4,042									
17080005070502	Yes	3,207	3,212	Yes	3,207	3,224	No	0	0	Yes	3,207	3,212
17080005070504	No	0	0									
17080005070505	No	0	0	No	0	0	Yes	2,877	2,900	No	0	0
17080005070605	No	0	0	Yes	3,060	3,067	No	0	0	No	0	0
17080005070606	Yes	4,140	4,169	Yes	4,140	4,169	No	0	0	Yes	4,140	4,169
17080005080101	Yes	4,210	4,238	Yes	4,210	4,238	No	0	0	Yes	4,210	4,238
17080005080102	Yes	3,622	3,629	Yes	3,622	3,629	Yes	3,622	3,671	Yes	3,622	3,629
17080005080201	Yes	5,414	5,475	Yes	5,414	5,475	No	0	0	Yes	5,414	5,475
17080005080202	No	0	0	No	0	0	Yes	4,607	4,631	No	0	0
17080005080203	No	0	0	No	0	0	Yes	6,647	6,674	No	0	0
17080005080301	Yes	2,757	2,816	Yes	2,757	2,816	Yes	2,757	2,766	Yes	2,757	2,816
17080005080303	No	0	0									
17080005080401	Yes	2,916	2,925	Yes	2,916	2,925	Yes	2,916	2,945	Yes	2,916	2,925
17080005080402	No	0	0									
17080005080403	No	0	0									
17080005080404	Yes	2,213	2,244									
17080005080405	Yes	2,630	2,670									
17080005080406	No	0	0									

## Crossover Alternative and Alternative Options

Subwatershed ID	Crossover Alternative			Crossover Option 1			Crossover Option 2			Crossover Option 3		
	Crossed?	Pre-Project Immature (ac)	Post-Project Immature (ac)	Crossed?	Pre-Project Immature (ac)	Post-Project Immature (ac)	Crossed?	Pre-Project Immature (ac)	Post-Project Immature (ac)	Crossed?	Pre-Project Immature (ac)	Post-Project Immature (ac)
17080001060304	Yes	288	296	Yes	288	296	Yes	288	296	Yes	288	296
17080001060501	Yes	3,792	3,793	Yes	3,792	3,793	Yes	3,792	3,793	Yes	3,792	3,793
17080001060502	Yes	5,207	5,226	Yes	5,207	5,222	Yes	5,207	5,226	Yes	5,207	5,226
17080001060503	No	0	0	No	0	0	No	0	0	No	0	0
17080001060504	Yes	6,903	6,907	Yes	6,903	6,907	Yes	6,903	6,907	Yes	6,903	6,907
17080001060506	Yes	1,484	1,539	Yes	1,484	1,539	Yes	1,484	1,539	Yes	1,484	1,539
17080001060601	Yes	3,767	3,768	Yes	3,767	3,768	Yes	3,767	3,768	Yes	3,767	3,768
17080001060602	Yes	5,798	5,798	Yes	5,798	5,804	Yes	5,798	5,798	Yes	5,798	5,798
17080001060603	No	0	0	No	0	0	No	0	0	No	0	0
17080001060605	No	0	0	No	0	0	No	0	0	No	0	0
17080001060606	No	0	0	No	0	0	No	0	0	No	0	0
17080001090106	No	0	0	No	0	0	No	0	0	No	0	0
17080001090109	No	0	0	No	0	0	No	0	0	No	0	0
17080001090110	No	0	0	No	0	0	No	0	0	No	0	0
17080001090112	No	0	0	No	0	0	No	0	0	No	0	0
17080001090115	No	0	0	No	0	0	No	0	0	No	0	0
17080001090116	No	0	0	No	0	0	No	0	0	No	0	0
17080001090117	No	0	0	No	0	0	No	0	0	No	0	0
17080001090118	No	0	0	No	0	0	No	0	0	No	0	0
17080001090119	No	0	0	No	0	0	No	0	0	No	0	0
17080001090126	No	0	0	No	0	0	No	0	0	No	0	0
17080001090128	No	0	0	No	0	0	No	0	0	No	0	0
17080001090134	No	0	0	No	0	0	No	0	0	No	0	0
17080002040502	No	0	0	No	0	0	No	0	0	No	0	0
17080002040505	No	0	0	No	0	0	No	0	0	No	0	0
17080002050401	Yes	3,206	3,236	Yes	3,206	3,236	Yes	3,206	3,236	Yes	3,206	3,236
17080002050403	Yes	270	296	Yes	270	296	Yes	270	296	Yes	270	296
17080002050405	Yes	97	123	Yes	97	123	Yes	97	123	Yes	97	123
17080002050501	No	0	0	No	0	0	No	0	0	No	0	0
17080002050502	No	0	0	No	0	0	No	0	0	No	0	0

17080002050503	Yes	1,455	1,463									
17080002050504	No	0	0									
17080002050505	No	0	0									
17080002050506	No	0	0									
17080002050508	Yes	181	212									
17080002050509	Yes	876	909									
17080002050603	No	0	0									
17080002050604	No	0	0									
17080002050605	No	0	0									
17080002050607	No	0	0									
17080002050608	No	0	0									
17080002050611	No	0	0									
17080002050612	No	0	0									
17080002050613	No	0	0									
17080002050615	No	0	0									
17080002060201	Yes	2,007	2,044									
17080002060203	Yes	1,556	1,614									
17080002060204	Yes	1,489	1,521									
17080002060302	No	0	0									
17080002060303	Yes	3,784	3,784									
17080002060304	Yes	2,736	2,742									
17080002060305	Yes	709	710									
17080002060402	No	0	0									
17080002060403	Yes	2,006	2,025									
17080002060404	Yes	6,759	6,787									
17080002060405	No	0	0									
17080002060406	Yes	6,260	6,264									
17080002060502	No	0	0									
17080002060503	Yes	5,293	5,299									
17080002060504	Yes	2,697	2,706									
17080003040302	No	0	0									
17080003040303	No	0	0									
17080003040401	No	0	0									
17080003040402	No	0	0									
17080003040403	No	0	0									

17080003040502	Yes	5,871	5,878									
17080003040503	Yes	3,010	3,014									
17080003040504	Yes	2,535	2,538									
17080003040505	Yes	4,010	4,023									
17080005070502	No	0	0	No	0	0	Yes	3,207	3,213	Yes	3,207	3,176
17080005070504	No	0	0	No	0	0	Yes	3,068	3,073	Yes	3,068	3,044
17080005070505	Yes	2,877	2,882	Yes	2,877	2,882	Yes	2,877	2,883	Yes	2,877	2,883
17080005070605	No	0	0									
17080005070606	No	0	0									
17080005080101	No	0	0									
17080005080102	No	0	0									
17080005080201	No	0	0									
17080005080202	Yes	4,607	4,614									
17080005080203	Yes	6,647	6,652									
17080005080301	No	0	0									
17080005080303	No	0	0									
17080005080401	No	0	0									
17080005080402	Yes	4,527	4,528									
17080005080403	Yes	2,731	2,749									
17080005080404	No	0	0									
17080005080405	No	0	0									
17080005080406	Yes	3,316	3,321									

## East Alternative and Alternative Options

Subwatershed ID	East Alternative			East Option 1			East Option 2			East Option 3		
	Crossed?	Pre-Project Immature (ac)	Post-Project Immature (ac)	Crossed?	Pre-Project Immature (ac)	Post-Project Immature (ac)	Crossed?	Pre-Project Immature (ac)	Post-Project Immature (ac)	Crossed?	Pre-Project Immature (ac)	Post-Project Immature (ac)
17080001060304	Yes	288	296	Yes	288	296	No	0	0	Yes	288	303
17080001060501	Yes	3,792	3,793	Yes	3,792	3,793	Yes	3,792	3,793	Yes	3,792	3,793
17080001060502	Yes	5,207	5,226	Yes	5,207	5,226	Yes	5,207	5,226	Yes	5,207	5,225
17080001060503	No	0	0	No	0	0	Yes	1,724	1,749	No	0	0
17080001060504	Yes	6,903	6,907	Yes	6,903	6,907	Yes	6,903	6,907	Yes	6,903	6,907
17080001060506	Yes	1,484	1,539	Yes	1,484	1,539	Yes	1,484	1,486	Yes	1,484	1,552
17080001060601	Yes	3,767	3,768	Yes	3,767	3,768	Yes	3,767	3,768	Yes	3,767	3,768
17080001060602	Yes	5,798	5,798	Yes	5,798	5,798	Yes	5,798	5,798	Yes	5,798	5,798
17080001060603	No	0	0	No	0	0	No	0	0	No	0	0
17080001060605	No	0	0	No	0	0	Yes	3,858	3,908	No	0	0
17080001060606	No	0	0	No	0	0	No	0	0	No	0	0
17080001090106	No	0	0	No	0	0	No	0	0	No	0	0
17080001090109	No	0	0	No	0	0	Yes	3,933	3,986	No	0	0
17080001090110	No	0	0	No	0	0	No	0	0	No	0	0
17080001090112	No	0	0	No	0	0	No	0	0	No	0	0
17080001090115	No	0	0	No	0	0	No	0	0	No	0	0
17080001090116	No	0	0	No	0	0	No	0	0	No	0	0
17080001090117	No	0	0	No	0	0	No	0	0	No	0	0
17080001090118	No	0	0	No	0	0	No	0	0	No	0	0
17080001090119	No	0	0	No	0	0	No	0	0	No	0	0
17080001090126	No	0	0	No	0	0	No	0	0	No	0	0
17080001090128	No	0	0	No	0	0	No	0	0	No	0	0
17080001090134	No	0	0	No	0	0	No	0	0	No	0	0
17080002040502	Yes	5,129	5,130	Yes	5,129	5,130	Yes	5,129	5,130	Yes	5,129	5,130
17080002040505	Yes	977	979	Yes	977	979	Yes	977	979	Yes	977	979
17080002050401	Yes	3,206	3,236	Yes	3,206	3,236	Yes	3,206	3,249	Yes	3,206	3,237
17080002050403	Yes	270	296	Yes	270	296	No	0	0	Yes	270	297
17080002050405	Yes	97	123	Yes	97	123	No	0	0	Yes	97	126
17080002050501	No	0	0	No	0	0	No	0	0	No	0	0
17080002050502	No	0	0	No	0	0	Yes	2,259	2,265	No	0	0

17080002050503	Yes	1,455	1,463	Yes	1,455	1,463	No	0	0	Yes	1,455	1,463
17080002050504	No	0	0	No	0	0	Yes	1,690	1,706	No	0	0
17080002050505	No	0	0									
17080002050506	No	0	0	No	0	0	Yes	854	873	No	0	0
17080002050508	Yes	181	212	Yes	181	212	No	0	0	Yes	181	214
17080002050509	Yes	876	909	Yes	876	909	No	0	0	Yes	876	911
17080002050603	No	0	0									
17080002050604	No	0	0									
17080002050605	No	0	0									
17080002050607	No	0	0									
17080002050608	No	0	0									
17080002050611	No	0	0									
17080002050612	No	0	0									
17080002050613	No	0	0									
17080002050615	No	0	0									
17080002060201	Yes	2,007	2,044	Yes	2,007	2,044	Yes	2,007	2,036	Yes	2,007	2,044
17080002060203	Yes	1,556	1,614	Yes	1,556	1,614	Yes	1,556	1,566	Yes	1,556	1,616
17080002060204	Yes	1,489	1,521	Yes	1,489	1,521	No	0	0	Yes	1,489	1,523
17080002060302	Yes	4,951	5,012									
17080002060303	Yes	3,784	3,841									
17080002060304	Yes	2,736	2,752									
17080002060305	Yes	709	714									
17080002060402	No	0	0									
17080002060403	No	0	0									
17080002060404	No	0	0									
17080002060405	No	0	0	No	0	0	Yes	5,288	5,315	No	0	0
17080002060406	No	0	0	No	0	0	Yes	6,260	6,269	No	0	0
17080002060502	No	0	0									
17080002060503	No	0	0									
17080002060504	No	0	0									
17080003040302	Yes	1,390	1,460									
17080003040303	Yes	614	631									
17080003040401	No	0	0									
17080003040402	Yes	2,117	2,137									
17080003040403	Yes	1,794	1,845									

17080003040502	No	0	0									
17080003040503	No	0	0									
17080003040504	No	0	0									
17080003040505	No	0	0									
17080005070502	Yes	3,207	3,212	No	0	0	Yes	3,207	3,212	Yes	3,207	3,212
17080005070504	No	0	0	Yes	3,068	3,084	No	0	0	No	0	0
17080005070505	No	0	0	Yes	2,877	2,890	No	0	0	No	0	0
17080005070605	No	0	0									
17080005070606	Yes	4,140	4,169	No	0	0	Yes	4,140	4,169	Yes	4,140	4,169
17080005080101	Yes	4,210	4,238	No	0	0	Yes	4,210	4,238	Yes	4,210	4,238
17080005080102	Yes	3,622	3,629	Yes	3,622	3,685	Yes	3,622	3,629	Yes	3,622	3,629
17080005080201	Yes	5,414	5,475	No	0	0	Yes	5,414	5,475	Yes	5,414	5,475
17080005080202	No	0	0	Yes	4,607	4,641	No	0	0	No	0	0
17080005080203	No	0	0	Yes	6,647	6,647	No	0	0	No	0	0
17080005080301	Yes	2,757	2,821	Yes	2,757	2,766	Yes	2,757	2,821	Yes	2,757	2,821
17080005080303	Yes	3,170	3,192	Yes	3,170	3,189	Yes	3,170	3,192	Yes	3,170	3,192
17080005080401	No	0	0	Yes	2,916	2,945	No	0	0	No	0	0
17080005080402	No	0	0									
17080005080403	No	0	0									
17080005080404	Yes	2,213	2,260	Yes	2,213	2,285	Yes	2,213	2,260	Yes	2,213	2,260
17080005080405	No	0	0									
17080005080406	No	0	0									

## West Alternative and Alternative Options

Subwatershed ID	West Alternative			West Option 1			West Option 2			West Option 3		
	Crossed?	Pre-Project Immature (ac)	Post-Project Immature (ac)	Crossed?	Pre-Project Immature (ac)	Post-Project Immature (ac)	Crossed?	Pre-Project Immature (ac)	Post-Project Immature (ac)	Crossed?	Pre-Project Immature (ac)	Post-Project Immature (ac)
17080001060304	No	0	0	No	0	0	No	0	0	No	0	0
17080001060501	Yes	3,792	3,793	Yes	3,792	3,793	Yes	3,792	3,793	Yes	3,792	3,793
17080001060502	No	0	0	No	0	0	Yes	5,207	5,214	Yes	5,207	5,228
17080001060503	No	0	0	No	0	0	No	0	0	No	0	0
17080001060504	No	0	0	No	0	0	No	0	0	Yes	6,903	6,907
17080001060506	No	0	0	No	0	0	No	0	0	No	0	0
17080001060601	Yes	3,767	3,768	Yes	3,767	3,768	Yes	3,767	3,768	Yes	3,767	3,768
17080001060602	Yes	5,798	5,806	Yes	5,798	5,804	Yes	5,798	5,806	Yes	5,798	5,798
17080001060603	Yes	4,759	4,765	Yes	4,759	4,760	Yes	4,759	4,767	Yes	4,759	4,765
17080001060605	No	0	0	No	0	0	No	0	0	No	0	0
17080001060606	No	0	0	No	0	0	No	0	0	Yes	3,434	3,439
17080001090106	Yes	3,763	3,767	Yes	3,763	3,767	Yes	3,763	3,767	Yes	3,763	3,767
17080001090109	No	0	0	No	0	0	No	0	0	No	0	0
17080001090110	Yes	6,978	6,979	Yes	6,978	6,979	Yes	6,978	6,979	Yes	6,978	6,979
17080001090112	No	0	0	No	0	0	No	0	0	No	0	0
17080001090115	Yes	1,882	1,882	Yes	1,882	1,882	Yes	1,882	1,882	Yes	1,882	1,882
17080001090116	Yes	998	998	Yes	998	998	Yes	998	998	Yes	998	998
17080001090117	Yes	1,111	1,111	Yes	1,111	1,111	Yes	1,111	1,111	Yes	1,111	1,111
17080001090118	Yes	6,645	6,645	Yes	6,645	6,645	Yes	6,645	6,645	Yes	6,645	6,645
17080001090119	Yes	1,720	1,720	Yes	1,720	1,720	Yes	1,720	1,720	Yes	1,720	1,720
17080001090126	Yes	701	701	Yes	701	701	Yes	701	701	Yes	701	701
17080001090128	Yes	3,064	3,064	Yes	3,064	3,064	Yes	3,064	3,064	Yes	3,064	3,064
17080001090134	No	0	0	Yes	3,376	3,376	No	0	0	No	0	0
17080002040502	No	0	0	No	0	0	No	0	0	No	0	0
17080002040505	No	0	0	No	0	0	No	0	0	No	0	0
17080002050401	No	0	0	No	0	0	No	0	0	No	0	0
17080002050403	No	0	0	No	0	0	No	0	0	No	0	0
17080002050405	No	0	0	No	0	0	No	0	0	No	0	0

17080002050501	No	0	0									
17080002050502	No	0	0									
17080002050503	No	0	0									
17080002050504	No	0	0									
17080002050505	No	0	0									
17080002050506	No	0	0									
17080002050508	No	0	0									
17080002050509	No	0	0									
17080002050603	Yes	5,000	5,005									
17080002050604	Yes	5,896	5,896									
17080002050605	No	0	0									
17080002050607	Yes	2,720	2,720									
17080002050608	Yes	1,900	1,906									
17080002050611	Yes	1,338	1,339									
17080002050612	Yes	4,403	4,404									
17080002050613	Yes	6,010	6,010									
17080002050615	Yes	2,280	2,280									
17080002060201	No	0	0									
17080002060203	No	0	0									
17080002060204	No	0	0									
17080002060302	No	0	0									
17080002060303	No	0	0									
17080002060304	No	0	0									
17080002060305	No	0	0									
17080002060402	No	0	0									
17080002060403	No	0	0									
17080002060404	No	0	0									
17080002060405	No	0	0									
17080002060406	No	0	0									
17080002060502	Yes	7,667	7,668									
17080002060503	Yes	5,293	5,305									
17080002060504	No	0	0									
17080003040302	No	0	0									
17080003040303	No	0	0									
17080003040401	No	0	0									

17080003040402	No	0	0									
17080003040403	No	0	0									
17080003040502	Yes	5,871	5,878									
17080003040503	Yes	3,010	3,014									
17080003040504	Yes	2,535	2,538									
17080003040505	Yes	4,010	4,021									
17080005070502	No	0	0									
17080005070504	No	0	0									
17080005070505	Yes	2,877	2,882									
17080005070605	No	0	0									
17080005070606	No	0	0									
17080005080101	No	0	0									
17080005080102	No	0	0									
17080005080201	No	0	0									
17080005080202	Yes	4,607	4,614									
17080005080203	Yes	6,647	6,652									
17080005080301	No	0	0									
17080005080303	No	0	0									
17080005080401	No	0	0									
17080005080402	Yes	4,527	4,528									
17080005080403	Yes	2,731	2,749									
17080005080404	No	0	0									
17080005080405	No	0	0									
17080005080406	Yes	3,316	3,321									

## APPENDIX B - RIPARIAN ASSESSMENT DATA

**Table B-1. Riparian conditions and effects at transmission line corridor crossings of fish-bearing streams.**

Crossing <sup>1</sup>	Latitude <sup>2</sup>	Longitude <sup>2</sup>	Stream Name	Stream Length (ft) <sup>3</sup>	Clearing Length (ft) <sup>4</sup>	Near-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>5</sup>	Near-term Riparian Function Rating <sup>6</sup>	Limits to Riparian Development <sup>7</sup>	Long-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>8</sup>	Long-term Riparian Function Rating <sup>9</sup>
1-1	46.2579	-122.9766	Delameter Creek	175	175	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	SW	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33
1-3	46.2232	-122.9647	Unnamed Tributary to Leckler Creek	154	154	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
1-4	46.2167	-122.9572		151	151	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
1-5	46.2023	-122.9430		151	151	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
1-6A	46.1866	-122.9288	Unnamed Tributary to Cowlitz River	288	288	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33
1-6B	46.1856	-122.9279		162	162	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33
1-6C	46.1848	-122.9247	Unnamed Tributary to Cowlitz River	585	439	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33
2-1	46.2584	-122.9761	Delameter Creek	175	0	Non-forested	0	NA	Non-forested	0
2-2	46.2536	-122.9724		233	0	Non-forested	0	NA	Non-forested	0
2-5	46.2367	-122.9594		162	0	Non-forested	0	NA	Non-forested	0
2-6	46.2345	-122.9577		261	261	Predominantly Hardwood Low LWD Potential Low Shade Hazard	0.33	W	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard	0.67
2-7A	46.2247	-122.9501	Leckler Creek	380	0	Non-forested	0	NA	Non-forested	0
2-7B	46.2240	-122.9496	Leckler Creek	384	0	Non-forested	0	NA	Non-forested	0
2-7C	46.2222	-122.9481	Leckler Creek	685	0	Non-forested	0	NA	Non-forested	0
2-8	46.2203	-122.9468	Unnamed Tributary to Leckler Creek	159	0	Non-forested	0	NA	Non-forested	0
2-9	46.2155	-122.9431		151	0	Non-forested	0	NA	Non-forested	0
2-10	46.2009	-122.9318		262	262	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
2-11	46.1929	-122.9256		164	164	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard	0.67	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
2-12	46.1862	-122.9181	Unnamed Tributary to Cowlitz River	165	0	Non-forested	0	NA	Non-forested	0
3-1	46.2587	-122.9758	Delameter Creek	175	175	Conifer/Hardwood Mixed Moderate LWD Potential	0.33	SW	Predominantly Conifer Moderate LWD Potential	0.33

Crossing <sup>1</sup>	Latitude <sup>2</sup>	Longitude <sup>2</sup>	Stream Name	Stream Length (ft) <sup>3</sup>	Clearing Length (ft) <sup>4</sup>	Near-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>5</sup>	Near-term Riparian Function Rating <sup>6</sup>	Limits to Riparian Development <sup>7</sup>	Long-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>8</sup>	Long-term Riparian Function Rating <sup>9</sup>
						High Shade Hazard			High Shade Hazard	
3-2	46.2556	-122.9717		168	168	Predominantly Conifer High LWD Potential High Shade Hazard	0.67	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
3-3	46.2485	-122.9540		167	167	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
3-4	46.2162	-122.9152	Sandy Bend Creek	154	154	Predominantly Hardwood Moderate LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed High LWD Potential High Shade Hazard	0.67
3-5	46.2162	-122.9125	Cowlitz River	211	0	Non-forested	0	NA	Non-forested	0
3-6	46.2051	-122.9029		363	363	Predominantly Conifer Moderate LWD Potential Low Shade Hazard	0.67	W	Predominantly Conifer Moderate LWD Potential Low Shade Hazard	0.67
3-7	46.1961	-122.8951	Unnamed Tributary to Ostrander Creek	153	153	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	W	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard	0.67
3-9	46.1963	-122.8853		153	0	Non-forested	0	NA	Non-forested	0
3-10	46.1960	-122.8823	Ostrander Creek	289	289	Predominantly Hardwood Moderate LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed High LWD Potential High Shade Hazard	0.67
4-1	46.1771	-122.9087	Cowlitz River	150	0	Non-forested	0	NA	Non-forested	0
5-1	46.1754	-122.8943		222	222	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
5-2	46.1778	-122.8778	Unnamed Tributary to Cowlitz River	244	244	Predominantly Conifer High LWD Potential High Shade Hazard	0.67	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
7-1	46.1949	-122.8707	South Fork Ostrander Creek	257	257	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
7-2	46.1941	-122.8624		151	151	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard	0.67	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
7-3	46.1904	-122.8457	Unnamed Tributary to South Fork Ostrander Creek	151	151	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
8-1	46.1826	-122.8514	South Fork Ostrander Creek	166	166	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
9-1	46.1706	-122.9024	Unnamed Tributary to Cowlitz River	178	178	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	SW	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33
9-2	46.1560	-122.8883		157	117	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33
9-3	46.1493	-122.8788	Unnamed Tributary to Coweeman River	218	0	Non-forested	0	NA	Non-forested	0

Crossing <sup>1</sup>	Latitude <sup>2</sup>	Longitude <sup>2</sup>	Stream Name	Stream Length (ft) <sup>3</sup>	Clearing Length (ft) <sup>4</sup>	Near-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>5</sup>	Near-term Riparian Function Rating <sup>6</sup>	Limits to Riparian Development <sup>7</sup>	Long-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>8</sup>	Long-term Riparian Function Rating <sup>9</sup>
9-4	46.1448	-122.8728	Unnamed Tributary to Ceweeman River	223	0	Non-forested	0	NA	Non-forested	0
9-5	46.1414	-122.8672	Ceweeman River	209	209	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	SW	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33
9-6	46.1390	-122.8637	Ceweeman River	151	0	Non-forested	0	NA	Non-forested	0
9-7	46.1360	-122.8591	Ceweeman River	155	0	Non-forested	0	NA	Non-forested	0
9-9	46.1131	-122.8253		1046	1046	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
9-10	46.1063	-122.8152	Unnamed Tributary to Turner Creek	166	166	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
9-11	46.0894	-122.7903		151	151	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
9-12	46.0775	-122.7727		175	175	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
9-13	46.0688	-122.7599		162	162	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
9-14	46.0680	-122.7587	Hatchery Creek	589	589	Conifer/Hardwood Mixed High LWD Potential High Shade Hazard	0.67	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
9-15	46.0581	-122.7440		228	228	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
9-16	46.0488	-122.7303		172	172	Predominantly Hardwood Moderate LWD Potential Low Shade Hazard	0.67	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
9-17	46.0424	-122.7210		220	220	Predominantly Hardwood Low LWD Potential Low Shade Hazard	0.33	W	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard	0.67
9-18	46.0412	-122.7192		157	157	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33
9-20A	46.0238	-122.6986		523	523	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33	SW	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33
9-20B	46.0220	-122.6973		245	245	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
9-21	46.0111	-122.6900	Kalama River	154	154	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	SW	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33
9-22	45.9941	-122.6784	Little Kalama River	223	223	Conifer/Hardwood Mixed Moderate LWD Potential	0.33	W	Predominantly Conifer Moderate LWD Potential	0.67

Crossing <sup>1</sup>	Latitude <sup>2</sup>	Longitude <sup>2</sup>	Stream Name	Stream Length (ft) <sup>3</sup>	Clearing Length (ft) <sup>4</sup>	Near-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>5</sup>	Near-term Riparian Function Rating <sup>6</sup>	Limits to Riparian Development <sup>7</sup>	Long-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>8</sup>	Long-term Riparian Function Rating <sup>9</sup>
						High Shade Hazard			Low Shade Hazard	
9-23	45.9910	-122.6763		186	0	Non-forested	0	NA	Non-forested	0
9-25	45.9782	-122.6679		158	158	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
9-26	45.9707	-122.6633		221	221	Predominantly Conifer High LWD Potential High Shade Hazard	0.67	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
10-1	46.1184	-122.7265	Unnamed Tributary to North Fork Goble Creek	236	236	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
10-2	46.1052	-122.7135	Goble Creek	150	150	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
10-3	46.0407	-122.6398	Kalama River	179	179	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	SW	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33
10-4	46.0380	-122.6365	Unnamed Tributary to Kalama River	150	150	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
11-1	46.1832	-122.8295	South Fork Ostrander Creek	260	260	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
11-3	46.1582	-122.7710	Ceweeman River	245	245	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	SW	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33
12-1	46.0152	-122.6345	Knowlton Creek	332	332	Predominantly Hardwood Moderate LWD Potential Low Shade Hazard	0.67	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
12-2	45.9964	-122.6349		100	100	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
14-1	45.9659	-122.6420		153	153	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard	0.67	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
15-1	45.9630	-122.6199		156	156	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
15-2	45.9601	-122.6002	Colvin Creek	229	229	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
18-1	45.9532	-122.5161		152	152	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
18-2	45.9532	-122.5094		185	185	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	W	Predominantly Conifer Moderate LWD Potential Low Shade Hazard	0.67
18-3	45.9532	-122.5034		151	151	Predominantly Conifer	1	N	Predominantly Conifer	1

Crossing <sup>1</sup>	Latitude <sup>2</sup>	Longitude <sup>2</sup>	Stream Name	Stream Length (ft) <sup>3</sup>	Clearing Length (ft) <sup>4</sup>	Near-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>5</sup>	Near-term Riparian Function Rating <sup>6</sup>	Limits to Riparian Development <sup>7</sup>	Long-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>8</sup>	Long-term Riparian Function Rating <sup>9</sup>
						High LWD Potential Low Shade Hazard			High LWD Potential Low Shade Hazard	
18-4	45.9532	-122.4969		177	177	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
18-5	45.9532	-122.4834		263	263	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
18-6	45.9533	-122.4646		357	357	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard	0.67	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
18-7	45.9526	-122.4180		210	210	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
18-8	45.9526	-122.4134		365	365	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
23-1	45.9564	-122.5797		155	155	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
25-1	45.9414	-122.6454	Unnamed Tributary to Houghton Creek	177	133	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
25-2	45.9402	-122.6446	Houghton Creek	159	119	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33
25-3	45.9380	-122.6433	Lewis River	151	151	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33
25-4	45.9362	-122.6422	Lewis River	165	165	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	S	Conifer/Hardwood Mixed High LWD Potential High Shade Hazard	0.67
25-5	45.9151	-122.6330		4	0	Non-forested	0	NA	Non-forested	0
25-7A	45.8893	-122.6334	Unnamed Tributary to Brezee Creek	1805	0	Non-forested	0	NA	Non-forested	0
25-7B	45.8785	-122.6337	Unnamed Tributary to Brezee Creek	566	424	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
25-8	45.8667	-122.6351	Riley Creek	171	128	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
25-9	45.8602	-122.6351	Riley Creek	203	152	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
25-10	45.8551	-122.6351	Lockwood Creek	152	152	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
25-11	45.8479	-122.6352	Unnamed Tributary to	160	120	Predominantly Hardwood	0.33	N	Conifer/Hardwood Mixed	1

Crossing <sup>1</sup>	Latitude <sup>2</sup>	Longitude <sup>2</sup>	Stream Name	Stream Length (ft) <sup>3</sup>	Clearing Length (ft) <sup>4</sup>	Near-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>5</sup>	Near-term Riparian Function Rating <sup>6</sup>	Limits to Riparian Development <sup>7</sup>	Long-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>8</sup>	Long-term Riparian Function Rating <sup>9</sup>
			East Fork Lewis River			Low LWD Potential High Shade Hazard			High LWD Potential Low Shade Hazard	
25-12A	45.8414	-122.6352		174	174	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard	0.67	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
25-12B	45.8408	-122.6352	Unnamed Tributary to East Fork Lewis River	177	177	Predominantly Hardwood Moderate LWD Potential Low Shade Hazard	0.67	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
25-13A	45.8366	-122.6347	Mason Creek	162	0	Non-forested	0	NA	Non-forested	0
25-13B	45.8354	-122.6345	Mason Creek	258	0	Non-forested	0	NA	Non-forested	0
25-14	45.8281	-122.6320	East Fork Lewis River	158	0	Non-forested	0	NA	Non-forested	0
25-15	45.8169	-122.6299	Unnamed Tributary to East Fork Lewis River	271	271	Predominantly Hardwood Moderate LWD Potential Low Shade Hazard	0.67	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
25-16A	45.8125	-122.6300	Unnamed Tributary to East Fork Lewis River	299	299	Predominantly Hardwood Low LWD Potential Low Shade Hazard	0.33	W	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard	0.67
25-16B	45.8112	-122.6300	Unnamed Tributary to East Fork Lewis River	1806	1806	Predominantly Hardwood Low LWD Potential Low Shade Hazard	0.33	W	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard	0.67
25-17	45.7994	-122.6299		150	112	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
25-18	45.7685	-122.6300		11	0	Non-forested	0	NA	Non-forested	0
25-19	45.7625	-122.6302		178	0	Non-forested	0	NA	Non-forested	0
25-20	45.7398	-122.6310	Unnamed Tributary to Mill Creek	157	157	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
25-21	45.7243	-122.6310	Salmon Creek	159	159	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33
25-22	45.7145	-122.6311		155	116	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
25-23	45.7042	-122.6311		198	149	Predominantly Hardwood Moderate LWD Potential Low Shade Hazard	0.67	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
26-1	45.9352	-122.5250		153	153	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
26-2	45.9339	-122.5239		178	178	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
26-3	45.9281	-122.5187	Cedar Creek	637	637	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	SW	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33
26-4	45.9076	-122.5039		155	155	Conifer/Hardwood Mixed Moderate LWD Potential	0.67	N	Predominantly Conifer High LWD Potential	1

Crossing <sup>1</sup>	Latitude <sup>2</sup>	Longitude <sup>2</sup>	Stream Name	Stream Length (ft) <sup>3</sup>	Clearing Length (ft) <sup>4</sup>	Near-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>5</sup>	Near-term Riparian Function Rating <sup>6</sup>	Limits to Riparian Development <sup>7</sup>	Long-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>8</sup>	Long-term Riparian Function Rating <sup>9</sup>
						Low Shade Hazard			Low Shade Hazard	
26-5	45.8988	-122.4875		342	342	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
26-6	45.8982	-122.4864		157	157	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
26-7	45.8795	-122.4595		305	305	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
28-1	45.9490	-122.3804		162	162	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
28-2	45.9412	-122.3741		198	198	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard	0.67	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
28-3	45.9312	-122.3724		150	150	Predominantly Hardwood Moderate LWD Potential High Shade Hazard	0.33	W	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
28-4	45.9255	-122.3715	Chelatchie Creek	155	155	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
28-5	45.9126	-122.3696	Unnamed Tributary to Cedar Creek	164	164	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
28-6	45.9048	-122.3696	Cedar Creek	153	153	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
28-7	45.8878	-122.3697		212	212	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
28-8	45.8866	-122.3697		154	154	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
30-1	45.8557	-122.4405		78	78	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
30-2	45.8512	-122.4380		167	167	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
30-3	45.8391	-122.4301	East Fork Lewis River	176	176	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	SW	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33
30-4	45.8316	-122.4246		162	162	Conifer/Hardwood Mixed High LWD Potential High Shade Hazard	0.67	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
30-5	45.7997	-122.3932		161	161	Conifer/Hardwood Mixed High LWD Potential	0.67	N	Predominantly Conifer High LWD Potential	1

Crossing <sup>1</sup>	Latitude <sup>2</sup>	Longitude <sup>2</sup>	Stream Name	Stream Length (ft) <sup>3</sup>	Clearing Length (ft) <sup>4</sup>	Near-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>5</sup>	Near-term Riparian Function Rating <sup>6</sup>	Limits to Riparian Development <sup>7</sup>	Long-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>8</sup>	Long-term Riparian Function Rating <sup>9</sup>
						High Shade Hazard			Low Shade Hazard	
30-6	45.7974	-122.3932		3	3	Predominantly Hardwood Moderate LWD Potential Low Shade Hazard	0.67	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
35-1	45.6801	-122.3315	Unnamed Tributary to Boulder Creek	251	251	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
35-2	45.6709	-122.3315	Little Washougal River	253	253	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
35-3	45.6687	-122.3315	East Fork Little Washougal River	164	164	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
36A-1	45.6565	-122.4840		386	386	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33
36A-2	45.6565	-122.4731		502	0	Non-forested	0	NA	Non-forested	0
36B-1	45.6556	-122.4826		248	248	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33
36B-2	45.6556	-122.4802		234	234	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33
36B-3	45.6556	-122.4713		226	226	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33
39-1	45.6568	-122.4171		152	152	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
39-2	45.6569	-122.3783		211	211	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
39-3	45.6569	-122.3766		208	208	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
39-4	45.6572	-122.3602		160	160	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
39-5	45.6569	-122.3494	Unnamed Tributary to Little Washougal River	289	289	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	SW	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33
39-6	45.6569	-122.3426	Little Washougal River	158	118	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
40-1	45.6526	-122.4824		155	155	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33
40-2	45.6408	-122.4690		274	0	Non-forested	0	NA	Non-forested	0

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40-3	45.6397	-122.4679		167	167	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33
40-4	45.6351	-122.4611		186	0	Non-forested	0	NA	Non-forested	0
43-1	45.6393	-122.4312		178	178	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	W	Predominantly Conifer Moderate LWD Potential Low Shade Hazard	0.67
43-2	45.6353	-122.4280		552	414	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33	W	Predominantly Conifer Moderate LWD Potential Low Shade Hazard	0.67
46-1	45.6354	-122.4488		173	0	Non-forested	0	NA	Non-forested	0
47-1	45.6354	-122.4373		181	0	Non-forested	0	NA	Non-forested	0
47-2	45.6354	-122.4280		181	0	Non-forested	0	NA	Non-forested	0
48-1	45.6354	-122.4248		903	0	Non-forested	0	NA	Non-forested	0
48-2	45.6354	-122.3757	Little Washougal River	279	279	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
49-1	45.6483	-122.3344	Unnamed Tributary to Little Washougal River	150	150	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
50-1	45.6320	-122.4398		150	150	Predominantly Hardwood Moderate LWD Potential Low Shade Hazard	0.67	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
50-2	45.6313	-122.4296		2194	1645	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	SW	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33
51-1	45.6250	-122.3742		153	0	Non-forested	0	NA	Non-forested	0
51-2	45.6229	-122.3741	Little Washougal River	162	0	Non-forested	0	NA	Non-forested	0
51-3	45.6182	-122.3735		151	0	Non-forested	0	NA	Non-forested	0
52-2	45.5867	-122.3778	Washougal River	159	0	Non-forested	0	NA	Non-forested	0
52-3	45.5800	-122.3969	Washougal River	151	0	Non-forested	0	NA	Non-forested	0
52-4	45.5793	-122.4029	Washougal River	164	164	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33
A-2	46.3374	-122.9788		257	257	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
A-3	46.3269	-122.9786	Baxter Creek	332	332	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
B-1	46.3181	-122.9743	Baxter Creek	151	151	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
B-2	46.3175	-122.9722		181	181	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
C-1	46.3055	-122.9804	Unnamed Tributary to Arkansas Creek	288	0	Non-forested	0	NA	Non-forested	0

Crossing <sup>1</sup>	Latitude <sup>2</sup>	Longitude <sup>2</sup>	Stream Name	Stream Length (ft) <sup>3</sup>	Clearing Length (ft) <sup>4</sup>	Near-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>5</sup>	Near-term Riparian Function Rating <sup>6</sup>	Limits to Riparian Development <sup>7</sup>	Long-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>8</sup>	Long-term Riparian Function Rating <sup>9</sup>
C-2	46.3041	-122.9804	Arkansas Creek	283	283	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	SW	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33
C-3	46.2894	-122.9803		245	0	Non-forested	0	NA	Non-forested	0
D-1	46.3046	-122.9793	Arkansas Creek	662	662	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
D-2	46.2900	-122.9792		171	171	Predominantly Hardwood Low LWD Potential High Shade Hazard	0.33	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
D-3	46.2818	-122.9791		22	22	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
E-1	46.2661	-122.9802	Monahan Creek	168	0	Non-forested	0	NA	Non-forested	0
F-1	46.3053	-122.9429	Whittle Creek	155	155	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
F-2	46.3011	-122.9298		153	153	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
F-3	46.2936	-122.9139	Cowlitz River	158	0	Non-forested	0	N	Non-forested	0
F-4	46.2939	-122.9085		160	160	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	W	Predominantly Conifer Moderate LWD Potential Low Shade Hazard	0.67
F-5	46.2940	-122.9003		177	177	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
F-6	46.2926	-122.8914	Salmon Creek	153	153	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
F-7	46.2890	-122.8844		166	166	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
F-8	46.2841	-122.8836		157	157	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
F-9A	46.2614	-122.8669	Coal Mine Creek	170	170	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard	0.67	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
F-9B	46.2610	-122.8665		186	186	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
F-10	46.2347	-122.8401		395	395	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
F-11	46.2303	-122.8337	Ostrander Creek	294	294	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1

Crossing <sup>1</sup>	Latitude <sup>2</sup>	Longitude <sup>2</sup>	Stream Name	Stream Length (ft) <sup>3</sup>	Clearing Length (ft) <sup>4</sup>	Near-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>5</sup>	Near-term Riparian Function Rating <sup>6</sup>	Limits to Riparian Development <sup>7</sup>	Long-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>8</sup>	Long-term Riparian Function Rating <sup>9</sup>
F-14	46.1903	-122.7713		470	470	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
F-15	46.1846	-122.7624		159	159	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
F-16	46.1806	-122.7562	Unnamed Tributary to Ceweeman River	150	150	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
F-17	46.1725	-122.7459	Ceweeman River	173	173	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	SW	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33
H-1	46.1282	-122.7355	North Fork Goble Creek	794	794	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard	0.67	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
I-1	46.1558	-122.7094		151	151	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
K-1	46.1260	-122.6300		301	301	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
K-2	46.1169	-122.6080		174	174	Conifer/Hardwood Mixed High LWD Potential High Shade Hazard	0.67	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
K-3	46.1085	-122.5879	Gobar Creek	150	150	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
K-4	46.1001	-122.5691		167	167	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
K-5	46.0863	-122.5450		329	329	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
K-6	46.0851	-122.5429		162	162	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
K-7	46.0762	-122.5275		158	158	Conifer/Hardwood Mixed High LWD Potential High Shade Hazard	0.67	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
K-8	46.0686	-122.5144	Kalama River	153	153	Conifer/Hardwood Mixed High LWD Potential High Shade Hazard	0.67	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
K-9	46.0337	-122.4528		163	163	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
K-10	46.0233	-122.4339		243	243	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1

Crossing <sup>1</sup>	Latitude <sup>2</sup>	Longitude <sup>2</sup>	Stream Name	Stream Length (ft) <sup>3</sup>	Clearing Length (ft) <sup>4</sup>	Near-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>5</sup>	Near-term Riparian Function Rating <sup>6</sup>	Limits to Riparian Development <sup>7</sup>	Long-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>8</sup>	Long-term Riparian Function Rating <sup>9</sup>
K-11	46.0160	-122.4022		151	151	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
K-12	46.0086	-122.3699		151	151	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
K-13	45.9937	-122.3529	Speelyai Creek	188	188	Predominantly Hardwood Moderate LWD Potential Low Shade Hazard	0.67	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
K-14	45.9575	-122.3543	Lewis River	175	175	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
L-1	45.9528	-122.5589	Lewis River	200	200	Conifer/Hardwood Mixed High LWD Potential High Shade Hazard	0.67	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
M-1	45.9518	-122.5656	Lewis River	204	204	Predominantly Hardwood Moderate LWD Potential High Shade Hazard	0.33	S	Conifer/Hardwood Mixed High LWD Potential High Shade Hazard	0.67
M-2	45.9431	-122.5456		167	167	Predominantly Conifer Moderate LWD Potential Low Shade Hazard	0.67	W	Predominantly Conifer Moderate LWD Potential Low Shade Hazard	0.67
M-3	45.9422	-122.5431	Pup Creek	163	163	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
O-1	45.9444	-122.3108	Canyon Creek	200	200	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
O-2	45.9071	-122.2924		189	189	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
O-3	45.8975	-122.2924		334	334	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
O-4	45.8896	-122.2925		167	167	Predominantly Conifer High LWD Potential High Shade Hazard	0.67	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
O-5	45.8753	-122.2925		157	157	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
O-6	45.8605	-122.2926		155	155	Predominantly Conifer Moderate LWD Potential High Shade Hazard	0.33	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
O-7	45.8265	-122.2928		212	212	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
O-8	45.8149	-122.2928	East Fork Lewis River	192	192	Predominantly Conifer High LWD Potential High Shade Hazard	0.67	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67

Crossing <sup>1</sup>	Latitude <sup>2</sup>	Longitude <sup>2</sup>	Stream Name	Stream Length (ft) <sup>3</sup>	Clearing Length (ft) <sup>4</sup>	Near-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>5</sup>	Near-term Riparian Function Rating <sup>6</sup>	Limits to Riparian Development <sup>7</sup>	Long-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>8</sup>	Long-term Riparian Function Rating <sup>9</sup>
O-9	45.8075	-122.2929		151	151	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard	0.67	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
O-10	45.8029	-122.2929	King Creek	159	159	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
O-11	45.7595	-122.2904	Unnamed Tributary to Coyote Creek	176	176	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
O-12	45.7559	-122.2904	Coyote Creek	152	152	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
O-14	45.7409	-122.2904		152	0	Non-forested	0	NA	Non-forested	0
O-15	45.7392	-122.2904	Rock Creek	154	154	Conifer/Hardwood Mixed High LWD Potential High Shade Hazard	0.67	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
O-16	45.6901	-122.2904	Jones Creek	339	339	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
P-1	45.7675	-122.3903		27	27	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
P-2	45.7631	-122.3907		157	157	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
P-3	45.7540	-122.3915		211	211	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
P-4	45.7523	-122.3917		155	155	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
P-5	45.7455	-122.3920		160	160	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
P-6	45.7215	-122.3928		1305	1305	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
P-7	45.7169	-122.3927		143	143	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
P-8	45.7146	-122.3902		173	173	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
P-9	45.7127	-122.3850		191	191	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
P-10	45.7075	-122.3709		364	364	Conifer/Hardwood Mixed High LWD Potential	1	N	Predominantly Conifer High LWD Potential	1

Crossing <sup>1</sup>	Latitude <sup>2</sup>	Longitude <sup>2</sup>	Stream Name	Stream Length (ft) <sup>3</sup>	Clearing Length (ft) <sup>4</sup>	Near-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>5</sup>	Near-term Riparian Function Rating <sup>6</sup>	Limits to Riparian Development <sup>7</sup>	Long-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>8</sup>	Long-term Riparian Function Rating <sup>9</sup>
						Low Shade Hazard			Low Shade Hazard	
P-11	45.7027	-122.3579		153	153	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
Q-1	45.6666	-122.3198	Jones Creek	150	150	Predominantly Conifer Moderate LWD Potential Low Shade Hazard	0.67	W	Predominantly Conifer Moderate LWD Potential Low Shade Hazard	0.67
Q-2	45.6654	-122.3211	East Fork Little Washougal River	1130	1130	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
R-1	45.6802	-122.2906		176	176	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
R-2	45.6749	-122.2908		50	50	Predominantly Conifer High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
R-3	45.6709	-122.2909	East Fork Little Washougal River	154	154	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
R-4A	45.6699	-122.2910		360	360	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
R-4B	45.6662	-122.2911		407	407	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
R-5	45.6564	-122.3112		158	118	Predominantly Hardwood Moderate LWD Potential Low Shade Hazard	0.67	N	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1
S-1	45.6531	-122.3307		324	324	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
T-1	45.6531	-122.3316		324	324	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
U-1	45.9412	-122.3278		153	153	Conifer/Hardwood Mixed Moderate LWD Potential High Shade Hazard	0.33	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
U-2	45.8990	-122.3439		172	0	Non-forested	0	NA	Non-forested	0
U-4	45.8940	-122.3481		253	253	Conifer/Hardwood Mixed High LWD Potential High Shade Hazard	0.67	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
V-1	45.8568	-122.3673		151	151	Conifer/Hardwood Mixed Moderate LWD Potential Low Shade Hazard	0.67	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
V-2	45.8446	-122.3667		185	185	Conifer/Hardwood Mixed Low LWD Potential High Shade Hazard	0.33	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
V-3	45.8381	-122.3665		170	170	Conifer/Hardwood Mixed	1	N	Predominantly Conifer	1

Crossing <sup>1</sup>	Latitude <sup>2</sup>	Longitude <sup>2</sup>	Stream Name	Stream Length (ft) <sup>3</sup>	Clearing Length (ft) <sup>4</sup>	Near-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>5</sup>	Near-term Riparian Function Rating <sup>6</sup>	Limits to Riparian Development <sup>7</sup>	Long-term Species Composition, LWD Recruitment Potential, and Stream Shade Hazard <sup>8</sup>	Long-term Riparian Function Rating <sup>9</sup>
						High LWD Potential Low Shade Hazard			High LWD Potential Low Shade Hazard	
V-4	45.8311	-122.3663		160	160	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
V-5	45.8157	-122.3658	East Fork Lewis River	170	170	Predominantly Conifer High LWD Potential High Shade Hazard	0.67	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
V-6	45.8050	-122.3706	Rock Creek	158	158	Predominantly Conifer High LWD Potential High Shade Hazard	0.67	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67
V-7	45.7995	-122.3797		165	165	Conifer/Hardwood Mixed High LWD Potential Low Shade Hazard	1	N	Predominantly Conifer High LWD Potential Low Shade Hazard	1
W-1	45.9553	-122.3512	Canyon Creek	153	153	Conifer/Hardwood Mixed High LWD Potential High Shade Hazard	0.67	S	Predominantly Conifer High LWD Potential High Shade Hazard	0.67

Notes: <sup>1</sup> Stream crossing designations include the BPA segment number and a consecutive identification number increasing from north to south.

<sup>2</sup> Location is approximate, determined by the intersection of the stream segments crossed and the transmission line center line; NAD83 Washington State Plan South Coordinate System.

<sup>3</sup> Length of fish-bearing streams occurring within the transmission line corridor based on the intersection of fish-bearing stream hydrography lines and the 150 ft BPA corridor.

<sup>4</sup> Length of fish-bearing streams cleared of forested vegetation based on aerial photo interpretation of the proportion of forested vegetation along the fish-bearing stream hydrography lines.

<sup>5</sup> Near-term species composition, LWD recruitment potential, and stream shade hazard ratings interpreted per WaFPP riparian assessment procedures (2011b) (see Tables 2 and 3).

<sup>6</sup> Near-term riparian function rating determined using Table 8 based on near-term LWD recruitment potential and stream shade hazard.

<sup>7</sup> Site factors limiting high LWD recruitment potential (W), low stream shade hazard (S), or both (SW); no limitations to high riparian function (N); and, non-forested crossings (NA).

<sup>8</sup> Projected long-term species composition, LWD recruitment potential, and stream shade hazard based on near-term riparian function and site limitations to riparian function (see Table 11).

<sup>9</sup> Long-term riparian function rating determined using Table 8 based on long-term LWD recruitment potential and stream shade hazard.

**Table B-2.** Cross-reference of alternatives and options by BPA transmission line corridor segment.

Segment	West	West Option 1	West Option 2	West Option 3	Central	Central Option 1	Central Option 2	Central Option 3	East	East Option 1	East Option 2	East Option 3	Crossover	Crossover Option 1	Crossover Option 2	Crossover Option 3
1							C2									
2	WA	W1	W2	W3									XA	X1	X2	X3
3									E1							
4	WA	W1	W2	W3				C2					XA	X1	X2	X3
5								C2								
7									E1							
8								C2								
9	WA	W1	W2	W3									XA	X1	X2	X3
10					CA	C1	C2	C3								
11								C2		E1						
12					CA	C1	C2	C3								
14													XA	X1	X2	X3
15					CA	C1	C2	C3					XA	X1	X2	X3
18					CA	C1	C2						XA	X1	X2	X3
23					CA	C1	C2	C3					XA	X1	X2	X3
25	WA	W1	W2	W3												
26								C3								
28					CA	C1	C2									
30									C3							
35					CA	C1	C2	C3			E2					
36		W1	W2	W3												
36A			W2	W3												
36B	WA															
37			W2	W3												
38			W2	W3												
39				W3												
40		W1														
41	WA															
43			W2													
45	WA															
46		W1														
47			W2										X1			
48			W2										X1			

49				W3	CA	C1	C2	C3	EA	E1	E2	E3	XA	X1	X2	X3
50	WA	W1												X1		
51			W2	W3	CA	C1	C2	C3	EA	E1	E2	E3	XA		X2	X3
52	WA	W1	W2	W3	CA	C1	C2	C3	EA	E1	E2	E3	XA	X1	X2	X3
A					C1											
B					CA	C1		C3	EA		E2	E3				
C															X2	
D																X3
E															X2	X3
F					CA	C1		C3	EA		E2	E3				
G					CA	C1		C3								
H					CA	C1	C2	C3								
I									EA		E2	E3				
J										E1						
K									EA	E1	E2	E3				
L					CA	C1	C2						XA	X1	X2	X3
M								C3								
N													XA	X1	X2	X3
O									EA	E1		E3	XA	X1	X2	X3
P					CA	C1	C2	C3			E2					
Q									EA	E1			XA	X1	X2	X3
R												E3				
S									EA	E1		E3	XA	X1	X2	X3
T			W3	CA	C1	C2	C3				E2					
U											E2					
V					CA	C1	C2				E2					
W									EA	E1	E2	E3	XA	X1	X2	X3

## APPENDIX C – FLOODPLAIN ASSESSMENT DATA

**Table C-1. Floodplain assessment data by stream crossing. Values are sorted according to Total Floodplain Impact Area; crossings with the greatest potential impact are at the bottom.**

Xing	Stream	Total Floodplain Area (acres) <sup>1</sup>	Impacts to Floodplain Vegetation (acres) <sup>2</sup>	Number of New Additional Towers <sup>3</sup>	Tower Footprint Area (acres) <sup>4</sup>	New or Reconstructed Roads in Corridor (lineal ft) <sup>5</sup>	New or Reconstructed Roads in Corridor (acres) <sup>6</sup>	Total Floodplain Impact Area (acres) <sup>7</sup>
9-5	Ceweeman River	1.2	0.0					0.00
18-5	Unnamed Tributary to Pup Creek	0.0	0.0					0.00
40-2	Unnamed Tributary to Lacamas Creek	1.4	0.0					0.00
51-1	Unnamed Tributary to Little Washougal R	0.0	0.0					0.00
52-3	Washougal River	2.3	0.0					0.00
2-1	Delameter Creek	0.0	0.0					0.00
C-2	Arkansas Creek	0.0	0.0					0.01
3-1	Delameter Creek	0.1	0.0					0.02
46-1	Lacamas Creek	2.5	0.0			81	0.02	0.02
52-4	Camas Slough	0.8	0.0			61	0.03	0.03
U-4	Cedar Creek	0.0	0.0					0.03
9-3	Unnamed Tributary to Ceweeman River	0.8	0.0					0.03
H-1	North Fork Goble Creek	0.0	0.0					0.04
1-6A	Unnamed Tributary to Cowlitz River	0.1	0.1					0.07
39-6	Little Washougal River	0.1	0.1					0.08
52-2	Washougal River	5.8	0.0			246	0.09	0.09
40-4	Unnamed Tributary to Lacamas Creek	7.4	0.0			128	0.07	0.09
25-13A	Mason Creek	0.5	0.1					0.09
3-4	Sandy Bend Creek	0.1	0.1					0.10
25-10	Lockwood Creek	0.2	0.1					0.11
O-9	Unnamed Tributary to King Creek	0.1	0.1					0.11
D-1	Arkansas Creek	0.1	0.1					0.12
8-1	South Fork Ostrander Creek	0.2	0.1					0.15
51-2	Little Washougal River	0.5	0.2					0.16

Xing	Stream	Total Floodplain Area (acres) <sup>1</sup>	Impacts to Floodplain Vegetation (acres) <sup>2</sup>	Number of New Additional Towers <sup>3</sup>	Tower Footprint Area (acres) <sup>4</sup>	New or Reconstructed Roads in Corridor (lineal ft) <sup>5</sup>	New or Reconstructed Roads in Corridor (acres) <sup>6</sup>	Total Floodplain Impact Area (acres) <sup>7</sup>
O-10	King Creek	0.2	0.2					0.16
25-21	Salmon Creek	1.0	0.2					0.17
39-1	Matney Creek	0.3	0.2	1	0.02			0.20
3-10	Ostrander Creek	2.4	0.1			183	0.09	0.22
Q-1	Jones Creek	0.4	0.3	1	0.00			0.29
11-1	South Fork Ostrander Creek	0.4	0.4					0.36
9-4	Unnamed Tributary to Coweeman River	0.7	0.4					0.36
F-6	Salmon Creek	0.5	0.4					0.38
36B-3	Unnamed Tributary to Lacamas Creek	5.7	0.1	1	0.08	517	0.25	0.41
9-6	Coweeman River	4.0	0.1	2	0.16	507	0.21	0.42
E-1	Monahan Creek	0.6	0.4					0.43
25-4	Lewis River	0.4	0.4					0.44
35-2	Little Washougal River	0.6	0.5					0.45
2-7	Leckler Creek	5.8	0.3	1	0.08	220	0.09	0.47
L-1	Lewis River	0.5	0.5					0.47
Q-2	East Fork Little Washougal River	0.5	0.5					0.48
1-6C	Unnamed Tributary to Cowlitz River	1.3	0.2	1	0.03	533	0.35	0.50
F-11	Ostrander Creek	0.5	0.5					0.51
9-7	Coweeman River	3.0	0.5			67	0.03	0.52
25-3	Lewis River	0.8	0.5					0.54
B-1	Baxter Creek	0.6	0.6					0.56
F-3	Cowlitz River	1.1	0.6					0.57
F-17	Coweeman River	0.6	0.6					0.60
50-2	Unnamed Tributary to Lacamas Creek	8.5	0.1	4	0.30	430	0.23	0.67
26-3	Cedar Creek	3.1	0.2			949	0.65	0.77
36A-2	Unnamed Tributary to Lacamas Creek	3.9	0.7	1	0.08	491	0.17	0.84
25-13B	Mason Creek	4.8	0.0	2	0.16	1,154	0.73	0.89
36A-1	Lacamas Creek	9.4	0.4	4	0.31	576	0.27	1.00
50-1	Unnamed Tributary to Lacamas Creek	1.5	1.2	1	0.08	56	0.02	1.18

Xing	Stream	Total Floodplain Area (acres) <sup>1</sup>	Impacts to Floodplain Vegetation (acres) <sup>2</sup>	Number of New Additional Towers <sup>3</sup>	Tower Footprint Area (acres) <sup>4</sup>	New or Reconstructed Roads in Corridor (lineal ft) <sup>5</sup>	New or Reconstructed Roads in Corridor (acres) <sup>6</sup>	Total Floodplain Impact Area (acres) <sup>7</sup>
3-7	Unnamed Tributary to Ostrander Creek	2.2	1.4					1.37
K-13	Speelyai Creek	1.6	1.6	1	0.08	317	0.21	1.60
40-3	Lacamas Creek	8.0	0.7	3	0.24	1,883	1.22	2.10
36B-1	Lacamas Creek	13.2	1.0	4	0.31	1,810	1.08	2.37
25-14	East Fork Lewis River	13.0	3.2	4	0.31	759	0.41	3.78
40-1	Lacamas Creek	25.2	3.7	6	0.47	1,155	0.54	4.53
52-5	Columbia River	14.2	4.4	4	0.26	1,831	1.02	5.38

<sup>1</sup>Total floodplain area (beyond the 100-ft riparian buffer) crossed by the transmission corridor at qualifying stream crossings.

<sup>2</sup>Existing forest canopy cover within the floodplain area that is greater than approximately 3 feet in height.

<sup>3</sup>Represents net additional towers within the floodplain area. Towers that are replaced or relocated are not included.

<sup>4</sup>Calculated as a 66-ft diameter circle at each tower location. Only portions of the circle that fall within the floodplain area are included.

<sup>5</sup>Represents length of new or reconstructed roads within the floodplain area.

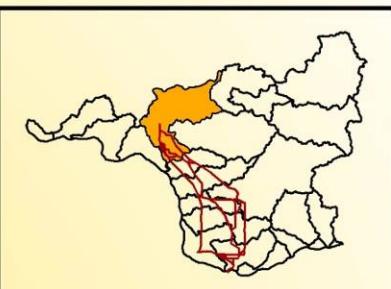
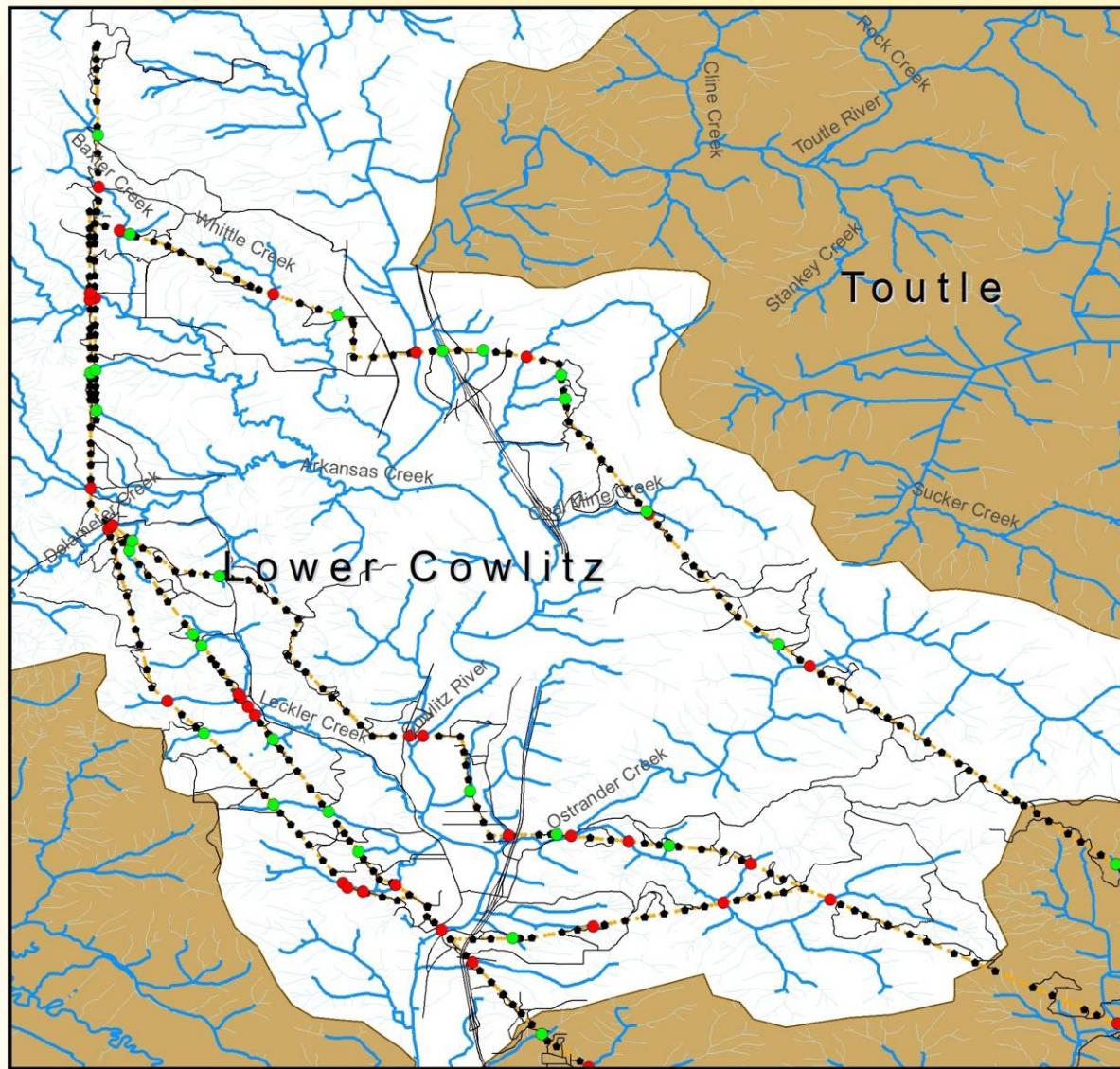
<sup>6</sup>Calculated as 30 ft width for new roads and 20 ft width for reconstructed roads.

<sup>7</sup>Sum of potential floodplain impacts within the transmission line corridor based on acreage of vegetation clearing, towers, and roads. Overlapping impact areas were accounted for in the summed values.

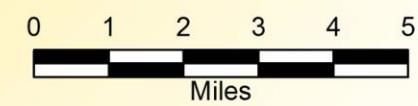
## **APPENDIX D – FISH ASSESSMENT DATA**

This Appendix includes figures showing EDT crossings within the major subbasins as well as tabular data of fish index values at the crossing-scale.

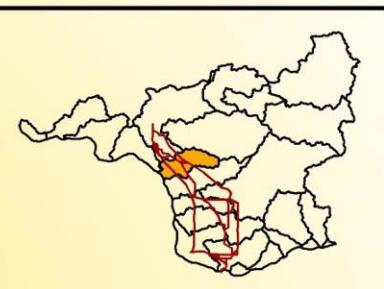
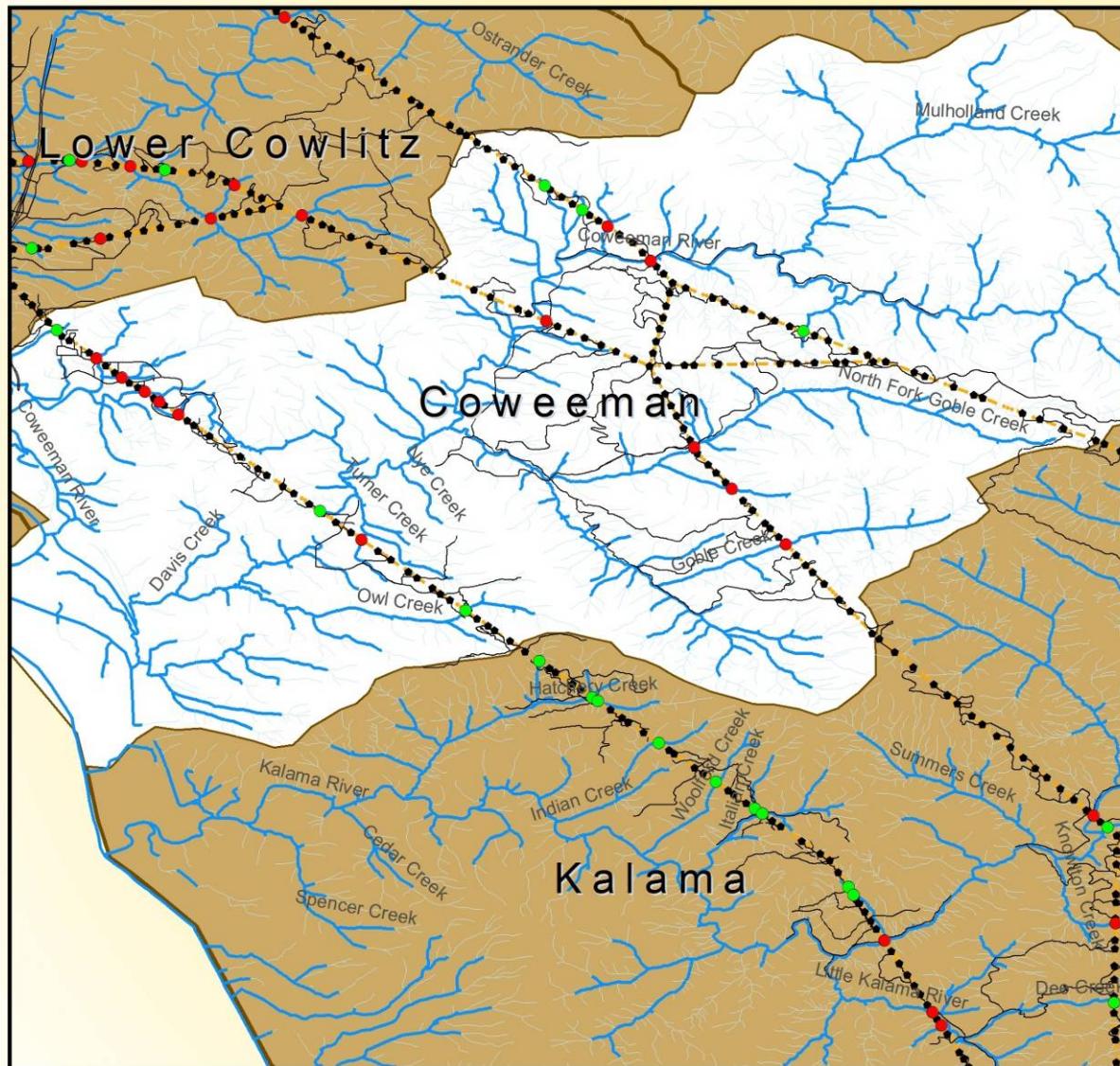
## Lower Cowlitz



June 2012



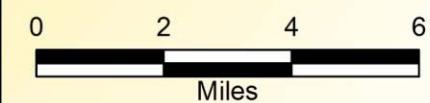
# C o w e e m a n



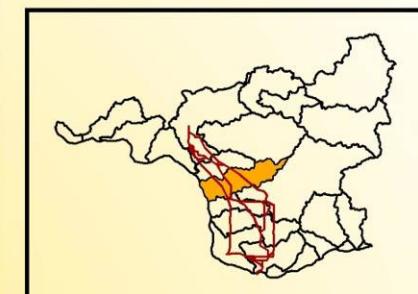
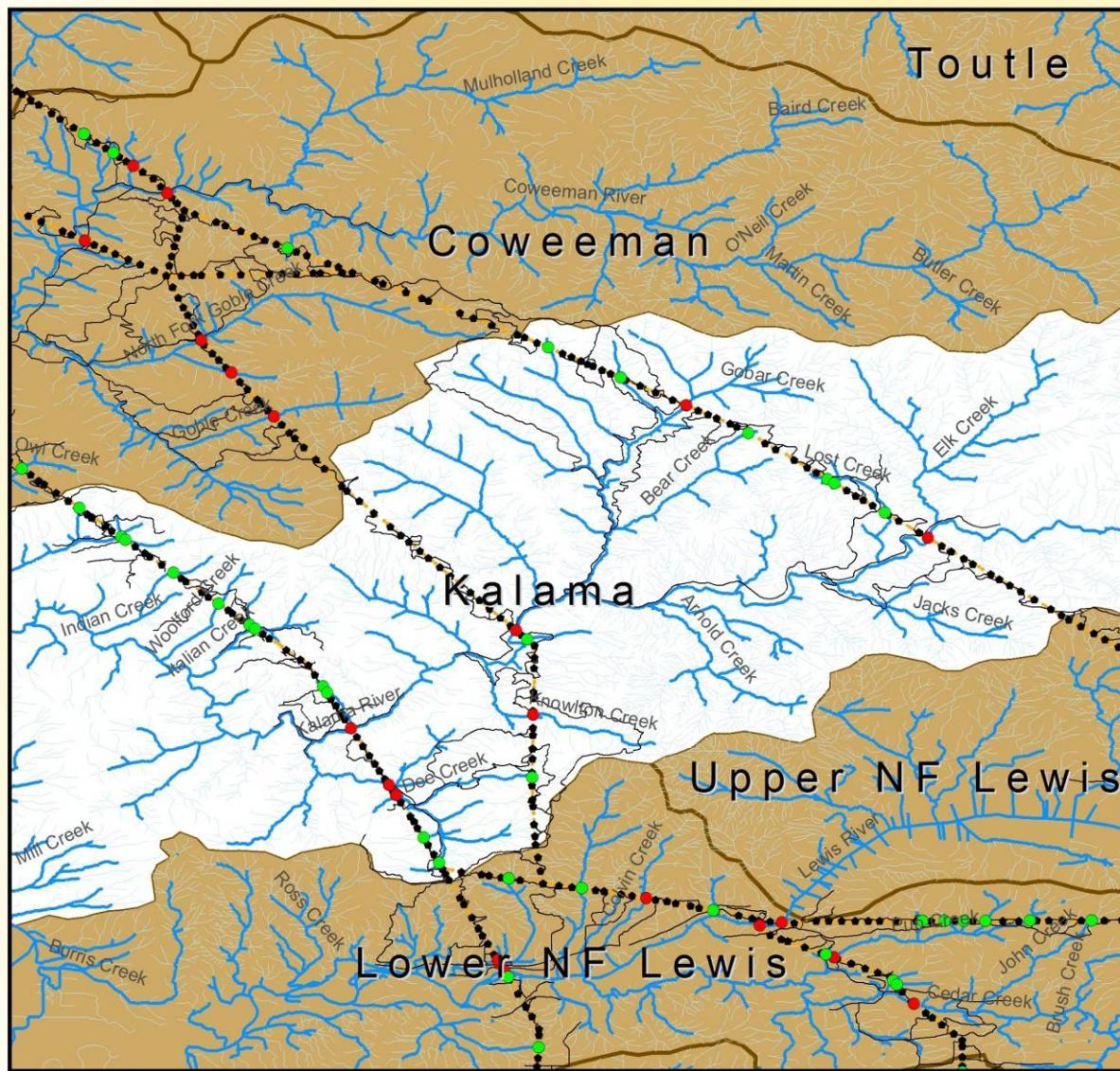
## Legend

- Non EDT Crossings
- EDT Crossings
- BPA Planned Structures
- BPA Planned Roads
- - - BPA Planned Tlines
- Fish Bearing Streams
- - - Non Fish Bearing Streams

June 2012



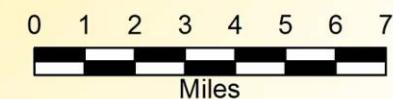
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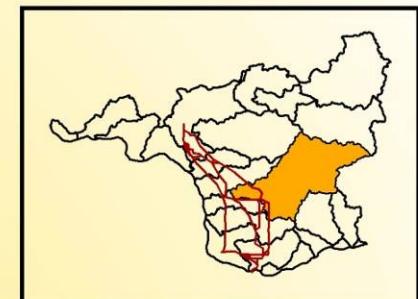
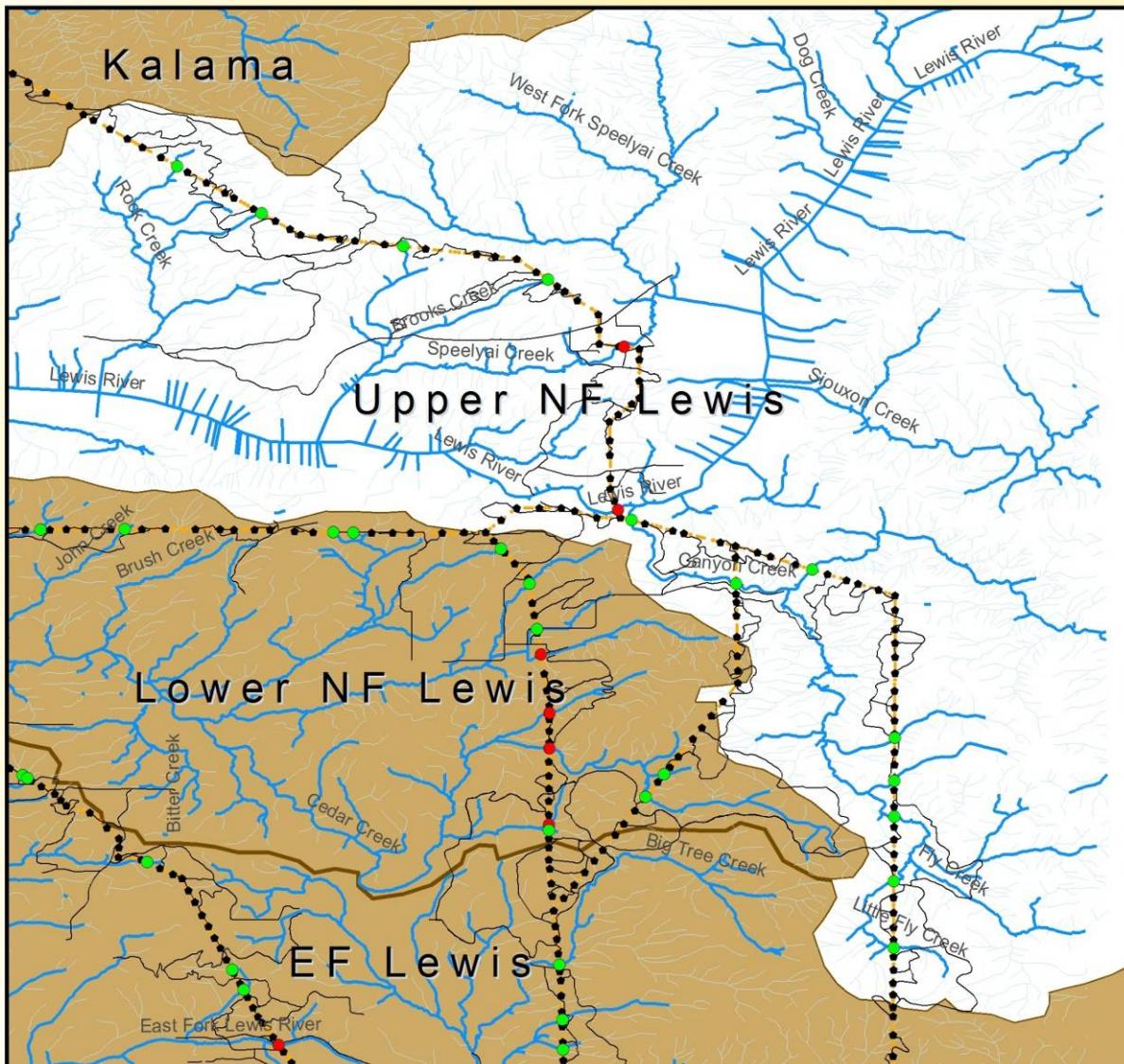
## Legend

- Non EDT Crossings
- EDT Crossings
- BPA Planned Structures
- BPA Planned Roads
- - - BPA Planned Tlines
- Fish Bearing Streams
- Non Fish Bearing Streams

June 2012



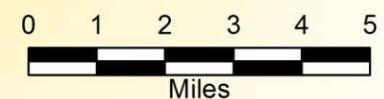
## Upper North Fork Lewis



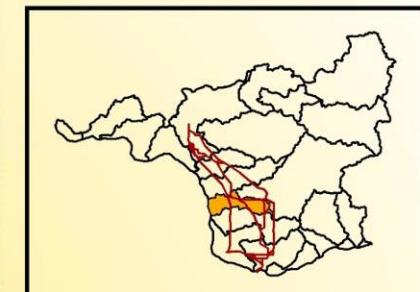
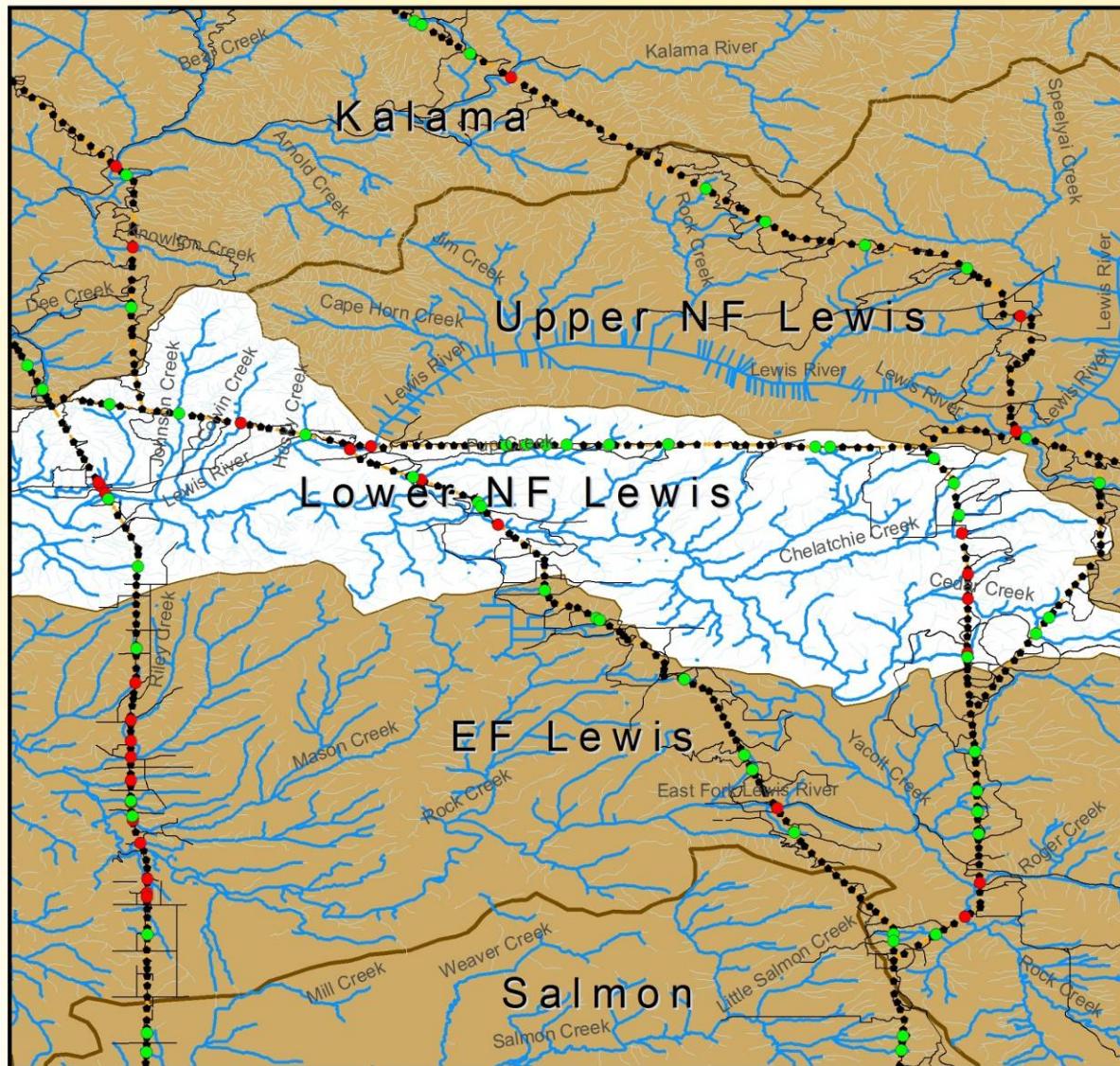
### Legend

- Non EDT Crossings
- EDT Crossings
- BPA Planned Structures
- BPA Planned Roads
- - - BPA Planned Tlines
- Fish Bearing Streams
- Non Fish Bearing Streams

June 2012



# Lower North Fork Lewis



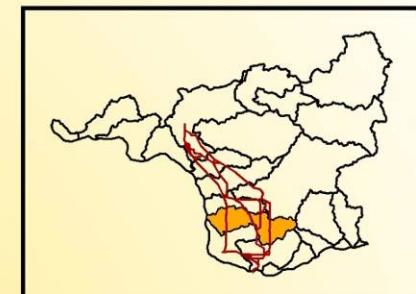
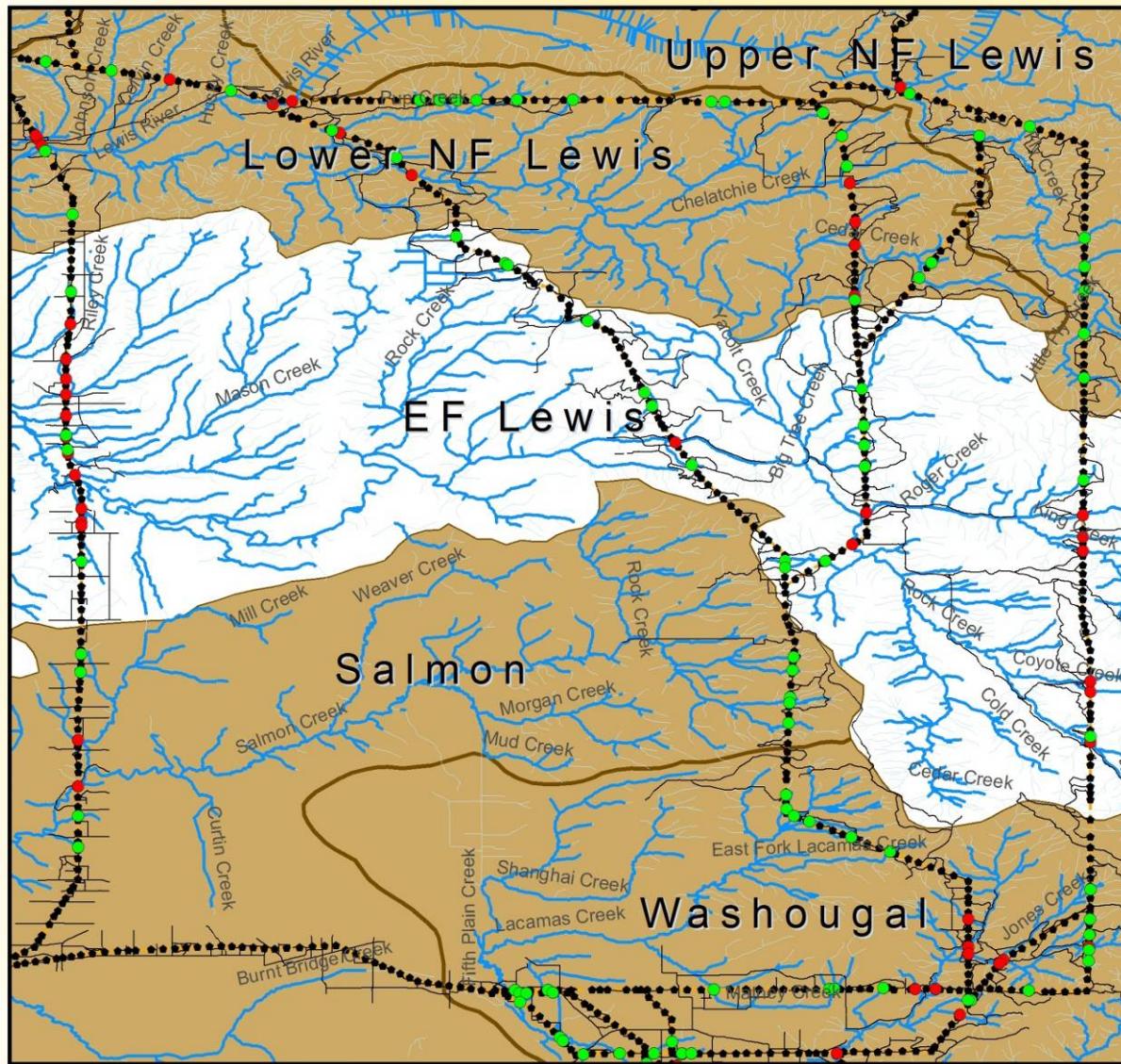
## Legend

- Non EDT Crossings
- EDT Crossings
- BPA Planned Structures
- BPA Planned Roads
- - - BPA Planned Tlines
- Fish Bearing Streams
- - Non Fish Bearing Streams

June 2012



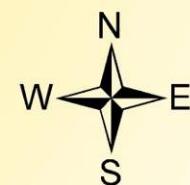
# East Fork Lewis



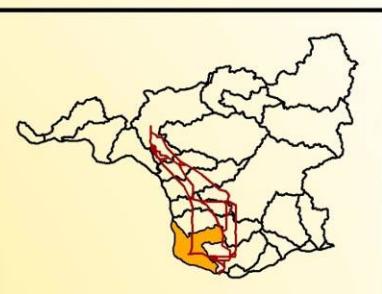
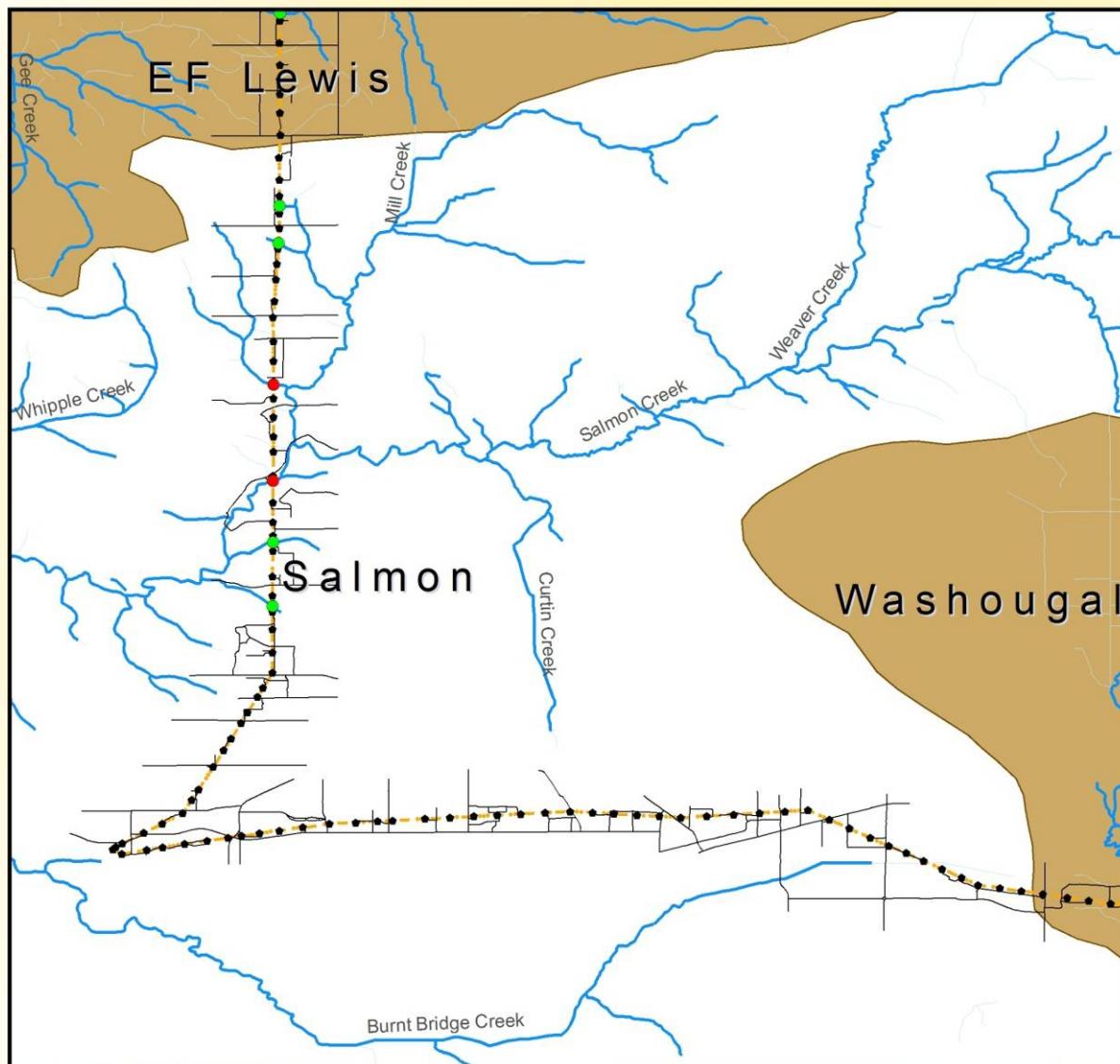
## Legend

- Non EDT Crossings
- EDT Crossings
- BPA Planned Structures
- BPA Planned Roads
- - - BPA Planned Tlines
- Fish Bearing Streams
- - - Non Fish Bearing Streams

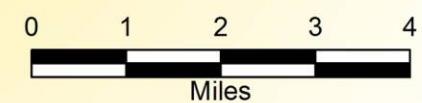
June 2012



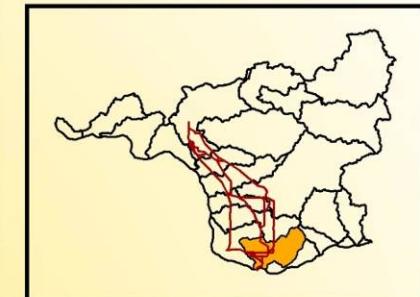
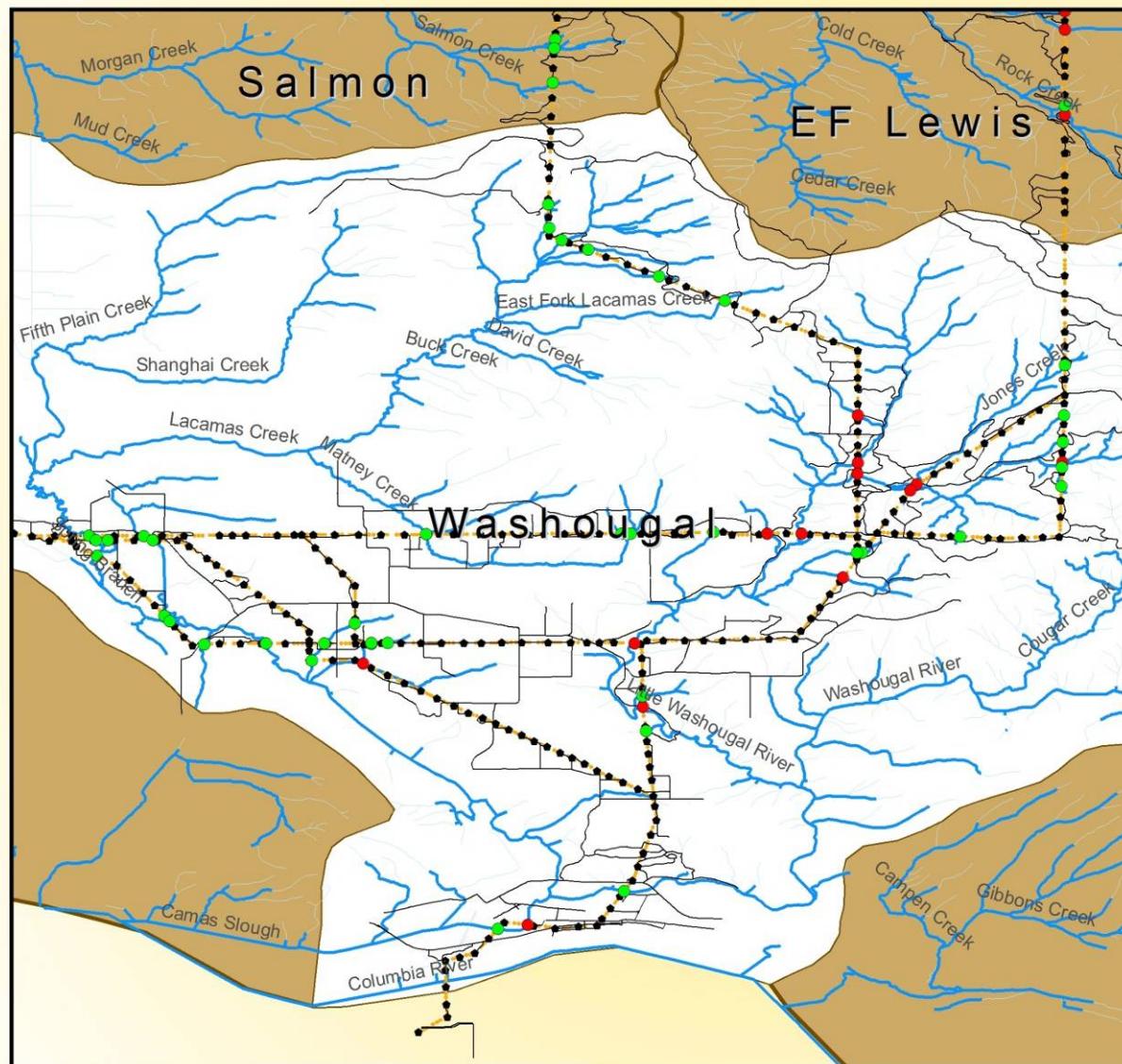
# Salmon



June 2012



# Washougal



## Legend

- Non EDT Crossings
- EDT Crossings
- BPA Planned Structures
- BPA Planned Roads
- - - BPA Planned Tlines
- Fish Bearing Streams
- Non Fish Bearing Streams

June 2012



**Table D-1. Fish Production Potential index values (number of adult fish produced in affected stream sections by species) for route crossings of significant anadromous salmon and steelhead streams. Crossings are sorted in decreasing order of the total value.**

Xing	Subbasin	Stream	EDT Reach	Coho	Chum	F Ck	S Ck	W Sh	S Sh	Total
25-3	LOWER NF LEWIS	Lewis River	Lewis 5	4.4	18.5	38.0	5.6	0.0	0.0	66.5
M-1	LOWER NF LEWIS	Lewis River	Lewis 7 B	0.3	0.4	29.2	9.3	0.3	0.0	39.5
L-1	LOWER NF LEWIS	Lewis River	Lewis 7 B	0.3	0.4	28.6	9.1	0.3	0.0	38.6
52-3	WASHOUGAL	Washougal River	Washougal 1 tidal	0.1	8.8	1.7	0.0	0.0	0.0	10.6
9-5	WASHOUGAL	Coweeman River	Coweeman 3	0.3	4.3	2.2	0.0	0.1	0.0	6.9
51-2	WASHOUGAL	Little Washougal River	Washougal 2 tidal	0.1	4.2	2.6	0.0	0.0	0.0	6.8
9-7	WASHOUGAL	Coweeman River	Coweeman 4 A	0.4	3.5	2.8	0.0	0.0	0.0	6.7
9-6	WASHOUGAL	Coweeman River	Coweeman 4 A	0.3	3.4	2.7	0.0	0.0	0.0	6.5
50-2	WASHOUGAL		Little Washougal 1 A & B	0.0	0.0	0.0	0.0	6.2	0.0	6.2
3-10	LOWER COWLITZ	Ostrander Creek	Ostrander Cr 1 B	3.1	2.9	0.0	0.0	0.0	0.0	6.1
Q-2	WASHOUGAL	East Fork Little Washougal River	Little Washougal 4 A	0.4	0.0	0.0	0.0	4.1	0.0	4.5
11-3	COWEEMAN	Coweeman River	Coweeman 7 & 8	0.4	0.0	3.7	0.0	0.2	0.0	4.3
F-17	COWEEMAN	Coweeman River	Coweeman 10	1.0	0.0	2.7	0.0	0.2	0.0	3.9
26-3	LOWER NF LEWIS	Cedar Creek	Cedar Cr 2 D	2.4	0.0	0.0	0.0	0.2	0.0	2.6
D-1	LOWER COWLITZ	Arkansas Creek	Arkansas Cr 3 A	2.5	0.0	0.0	0.0	0.0	0.0	2.5
39-6	WASHOUGAL	Little Washougal River	Little Washougal 2 C thru E	0.7	0.0	0.0	0.0	1.6	0.0	2.2
10-3	KALAMA	Kalama River	Kalama 9	0.0	0.0	0.0	0.5	0.8	0.3	1.5
2-7C	EF LEWIS	Leckler Creek	Leckler Cr 1 B	1.5	0.0	0.0	0.0	0.0	0.0	1.5
35-3	WASHOUGAL	East Fork Little Washougal River	Little Washougal 3	0.1	0.0	0.0	0.0	1.4	0.0	1.5
35-2	WASHOUGAL	Little Washougal River	Boulder Cr 1 A_C	0.1	0.0	0.0	0.0	1.2	0.0	1.3
F-3	LOWER COWLITZ	Cowlitz River	Lower Cowlitz-2 M	0.0	0.5	0.7	0.0	0.0	0.0	1.2
3-5	LOWER COWLITZ	Cowlitz River	Lower Cowlitz-2 H	0.0	0.7	0.3	0.0	0.0	0.0	1.0
4-1	WASHOUGAL	Cowlitz River	Lower Cowlitz-2 C	0.0	0.5	0.5	0.0	0.0	0.0	1.0
9-21	WASHOUGAL	Kalama River	Kalama 7	0.0	0.0	0.0	0.4	0.4	0.1	0.9
2-7B	EF LEWIS	Leckler Creek	Leckler Cr 1 B	0.8	0.0	0.0	0.0	0.0	0.0	0.9
H-1	COWEEMAN	North Fork Goble Creek	NF Goble Cr 1 B	0.1	0.0	0.0	0.0	0.7	0.0	0.8
48-2	WASHOUGAL	Little Washougal River	Little Washougal 1 A & B	0.0	0.0	0.0	0.0	0.8	0.0	0.8
V-6	EF LEWIS	Rock Creek	Rock Cr 1	0.0	0.0	0.0	0.0	0.8	0.0	0.8
25-13B	EF LEWIS	Mason Creek	M1_Mason Cr 1	0.7	0.0	0.0	0.0	0.0	0.0	0.8
C-2	LOWER COWLITZ	Arkansas Creek	Arkansas Cr 3 B	0.7	0.0	0.0	0.0	0.0	0.0	0.8
K-8	KALAMA	Kalama River	Kalama 15	0.0	0.0	0.0	0.3	0.0	0.4	0.7
7-1	LOWER COWLITZ	South Fork Ostrander Creek	SF Ostrander Cr 1	0.6	0.0	0.0	0.0	0.0	0.0	0.6
9-22	WASHOUGAL	Little Kalama River	LK1_Little Kalama 3	0.0	0.0	0.0	0.0	0.6	0.0	0.6
25-2	LOWER NF LEWIS	Houghton Creek	Houghton Cr 1 B	0.6	0.0	0.0	0.0	0.0	0.0	0.6
1-1	LOWER COWLITZ	Delameter Creek	Delameter Cr 3 A	0.5	0.0	0.0	0.0	0.0	0.0	0.5
2-1	LOWER COWLITZ	Delameter Creek	Delameter Cr 3 A	0.5	0.0	0.0	0.0	0.0	0.0	0.5
3-1	LOWER COWLITZ	Delameter Creek	Delameter Cr 3 A	0.5	0.0	0.0	0.0	0.0	0.0	0.5

Xing	Subbasin	Stream	EDT Reach	Coho	Chum	F Ck	S Ck	W Sh	S Sh	Total
25-21	SALMON	Salmon Creek	Salmon17	0.3	0.0	0.2	0.0	0.0	0.0	0.5
F-1	LOWER COWLITZ	Whittle Creek	Whittle Cr 2	0.5	0.0	0.0	0.0	0.0	0.0	0.5
25-14	EF LEWIS	East Fork Lewis River	M1_Mason Cr 1	0.4	0.0	0.0	0.0	0.0	0.0	0.5
2-7A	EF LEWIS	Leckler Creek	Leckler Cr 2	0.4	0.0	0.0	0.0	0.0	0.0	0.4
O-8	EF LEWIS	East Fork Lewis River	EF Lewis 16	0.0	0.0	0.0	0.0	0.0	0.4	0.4
F-11	LOWER COWLITZ	Ostrander Creek	Ostrander Cr 2	0.3	0.0	0.0	0.0	0.1	0.0	0.4
V-5	EF LEWIS	East Fork Lewis River	EF Lewis 14 A	0.0	0.0	0.0	0.0	0.3	0.1	0.4
1-3	LOWER COWLITZ	Unnamed Tributary to Leckler Creek	Leckler Cr RB Trib 2	0.4	0.0	0.0	0.0	0.0	0.0	0.4
3-4	LOWER COWLITZ	Sandy Bend Creek	Sandy Bend Cr	0.4	0.0	0.0	0.0	0.0	0.0	0.4
3-7	LOWER COWLITZ	Unnamed Tributary to Ostrander Creek	Ostrander RB Trib 1	0.3	0.0	0.0	0.0	0.0	0.0	0.3
O-9	EF LEWIS		EF Lewis 16	0.0	0.0	0.0	0.0	0.0	0.3	0.3
25-10	EF LEWIS	Lockwood Creek	L1_Lockwood Cr 1	0.3	0.0	0.0	0.0	0.1	0.0	0.3
30-3	EF LEWIS	East Fork Lewis River	EF Lewis 11	0.0	0.0	0.0	0.0	0.3	0.1	0.3
9-23	WASHOUGAL		LK1_Little Kalama 4	0.0	0.0	0.0	0.0	0.3	0.0	0.3
25-20	SALMON	Unnamed Tributary to Mill Creek	RBtrib2-1 (MillCr)	0.3	0.0	0.0	0.0	0.0	0.0	0.3
9-4	WASHOUGAL	Unnamed Tributary to Coweeman River	Coweeman RB Trib 1 B	0.3	0.0	0.0	0.0	0.0	0.0	0.3
39-5	WASHOUGAL	Unnamed Tributary to Little Washougal River	Little Wa RB Trib 2 C	0.1	0.0	0.0	0.0	0.2	0.0	0.3
F-16	COWEEMAN	Unnamed Tributary to Coweeman River	Coweeman RB Trib 7 (26.0079)	0.3	0.0	0.0	0.0	0.0	0.0	0.3
O-15	EF LEWIS	Rock Creek	Rock Cr 5 B	0.0	0.0	0.0	0.0	0.2	0.0	0.2
28-5	LOWER NF LEWIS	Unnamed Tributary to Cedar Creek	Booty Cr 1	0.2	0.0	0.0	0.0	0.0	0.0	0.2
11-1	LOWER COWLITZ	South Fork Ostrander Creek	SF Ostrander Cr 3	0.2	0.0	0.0	0.0	0.0	0.0	0.2
28-4	LOWER NF LEWIS	Chelatchie Creek	Big Cr 2	0.2	0.0	0.0	0.0	0.0	0.0	0.2
M-3	LOWER NF LEWIS	Pup Creek	Pup Cr 1 C	0.1	0.0	0.0	0.0	0.1	0.0	0.2
K-3	KALAMA	Gobar Creek	G1_Gobar Cr 5	0.0	0.0	0.0	0.0	0.2	0.0	0.2
25-9	EF LEWIS	Riley Creek	L1_Riley Cr 1	0.1	0.0	0.0	0.0	0.1	0.0	0.2
9-10	WASHOUGAL	Unnamed Tributary to Turner Creek	T1_Turner Cr LB Trib LB Trib	0.2	0.0	0.0	0.0	0.0	0.0	0.2
25-8	EF LEWIS	Riley Creek	L1_Riley Cr 1	0.1	0.0	0.0	0.0	0.1	0.0	0.1
10-2	COWEEMAN	Goble Creek	Goble Cr 3	0.0	0.0	0.0	0.0	0.1	0.0	0.1
10-1	COWEEMAN	Unnamed Tributary to North Fork Goble Creek	NF Goble Cr LB Trib 1	0.1	0.0	0.0	0.0	0.0	0.0	0.1
9-3	WASHOUGAL	Unnamed Tributary to Coweeman River	Coweeman RB Trib 1 RB Trib	0.1	0.0	0.0	0.0	0.0	0.0	0.1
R-3	WASHOUGAL	East Fork Little Washougal River	Little Washougal 5	0.1	0.0	0.0	0.0	0.0	0.0	0.1
A-3	LOWER COWLITZ	Baxter Creek	Baxter Cr 1 B	0.1	0.0	0.0	0.0	0.0	0.0	0.1
49-1	WASHOUGAL	Unnamed Tributary to Little Washougal River	Jackson Family Cr 4	0.1	0.0	0.0	0.0	0.0	0.0	0.1

## **Appendix L**

### **Wetland Modeling and Analysis**



*Herrera Environmental Consultants, Inc.*

**Memorandum**

**To** Tish Eaton  
**cc** Nancy Wittpenn  
**From** Herrera Environmental Consultants/Golder Associates Inc.  
**Date** March 5, 2012  
**Subject** BPA I-5 Corridor Reinforcement Project, GIS Modeling Methods Used to Update Wetland Boundary Maps and Assess Wetland Functions

Bonneville Power Administration (BPA) requested development of a geographic information system (GIS) model to accomplish two objectives:

- Improve accuracy of wetland boundary maps in a systematic, automated, and detailed manner in the I-5 Corridor Reinforcement Project study area
- Evaluate wetland functions for those wetlands

This memo includes descriptions of methods used to develop and apply the GIS models to accomplish BPA's objectives.

Existing mapping resources used for these analyses included:

- Broad coverage aerial photography (USDA 2009)
- Project corridor high-resolution aerial photograph (0.5-foot pixels) and LiDAR (3-foot pixels) (BPA 2011)
- LANDSAT imagery (USGS 2001)
- National Wetlands Inventory (NWI) (USFWS 2010)
- Hydrography data (stream locations) for Cowlitz County and Clark County (WDNR 2006)
- Clark County and Cowlitz County soil surveys (NRCS 2009)
- Hydric soils list for Washington (NRCS 2010)
- Washington Department of Fish and Wildlife (WDFW) Priority Habitats and Species (PHS) data (WDFW 2010)

## Update Wetland Boundary Maps

The GIS model analyzed several spatial datasets strongly correlated with wetland presence to generate a map showing the relative aggregate potential (High, Medium, or Low) for a given area to contain wetlands. This model and the parameters used in its development are described in detail in the following section.

The model was run in six test sites: Test Site 1 is along the Cowlitz River (Segment 3); Test Site 2 includes the Coweeman River crossing (Segment 9), Test Site 3 includes the East Fork of the Lewis River (Segment 25), Test Site 4 is near Chilatchie (Segment 28), Test Site 5 is the Casey Substation site, and Test Site 6 is the Baxter Road Substation site. Wetlands at test sites 1 through 4 had been mapped previously using existing available information including hydric soil and wetland inventory maps, topographic maps, and recent aerial photographs, and had not been delineated on the ground. Wetlands at the Casey and Baxter Road Substation sites (test sites 5 and 6) had been mapped previously by wetland delineations conducted on those sites.

Following model output and map generation, Herrera wetland scientists compared the results of the GIS model to previous mapping results. Wetland scientists visited the four test sites that had not been previously delineated to compare wetland conditions on the ground to the model output and the wetland mapping completed previously. These site visits were completed on November 9 and 10, 2011. The results of the GIS model mapping effort and comparisons to previously mapped wetlands at the six test sites are described in the section of this memo titled *Compare Results of Original Wetland Mapping and GIS Wetland Potential Model*.

### GIS Mapping Model

BPA acquired LiDAR data and high-resolution aerial imagery (BPA 2011) within 400 feet of the four proposed project alternatives to support its design process. Herrera, Golder, and BPA discussed options for using this data to improve the accuracy of the predicted wetland acreage in the discipline reports prepared in 2010. LiDAR data were not available when the wetland report was written. Applying LiDAR to the same alternatives allows additional information to be applied to the wetland mapping and assumptions.

One limitation of relying primarily on aerial photography to map wetland boundaries is that canopy cover makes it difficult to identify wetlands in forested areas. LiDAR data that penetrates canopy and detects bare-ground depressions is a valuable addition to a wetland boundary analysis, because it provides the potential for detecting more forested wetland and confirming the presence of previously mapped wetlands. Herrera incorporated the new LiDAR data into a wetland prediction GIS model intended to refine the previous wetland mapping conducted in 2010. The GIS model is a matrix-based analysis approach for identifying wetland presence potential through the following steps:

- Identify available spatial datasets that are most predictive of wetland presence

- Apply scientific expertise to rank each dataset into low-to-high categories based on correlation with wetland presence
- Overlay and add the ranked datasets together to obtain an overall assessment of wetland presence potential

The following sections describe these steps in more detail, including data sources used and model methodology.

### *Spatial Datasets*

The following five data sets were identified by Herrera biologists and the GIS analyst as having a strong correlation with on-the-ground wetland presence and were used to develop the wetland prediction GIS model.

#### *National Wetland Inventory (NWI) Wetland Boundaries*

NWI wetlands mapped by USFWS are a very useful dataset for predicting wetland presence. This data was obtained from the original GIS mapping effort for incorporation into the model.

#### *Hydric Soils*

Soil data classified as non-hydric, hydric, or partially hydric was obtained from NRCS for incorporation into the model. Both hydric and partially hydric soil types are correlated with wetland presence.

#### *LiDAR Topographic Depressions*

A percentage of topographic depressions in LiDAR indicate areas that may flood such as lakes and wetlands. Although some topographic depressions may not be wetlands and may be data anomalies or other types of graded areas, using topographic depression information can help to determine whether a specific location in the overall aggregate model is likely to be a wetland.

#### *LiDAR Topographic Wetness Index (TWI)*

The Topographic Wetness Index is derived from LiDAR data and combines slope and upslope contributing drainage area on a pixel-by-pixel basis to determine where water is most likely to accumulate when it is present in the landscape. TWI is not a direct measure of on-the-ground wetness, but instead indicates overall potential for wetness.

#### *Landsat Band 5 Spectral Data*

Band 5 (near-infrared spectral band) of remotely sensed Landsat satellite is extremely sensitive to water presence. Herrera extracted this data for the month of March for multiple years from data with 30-meter pixel resolution. The March timeframe was selected because it represent the

early part of the growing season in western Washington and Oregon, when wetland plants are growing and water presence is detectable. Several known wetland areas were mapped, and the Band 5 data was used to run statistical analysis on minimum, maximum, and standard deviation brightness values correlated with each wetland. The results of this analysis were used to extract the brightness values most strongly correlated with on-the-ground wetland presences.

#### *Ranking and Matrix Development*

Herrera biologists prepared a scoring scheme for each spatial dataset based on potential for wetland presence. Each dataset is scored on a scale of '0' to '3'. A value of '0' indicates a low probability of wetland presence for that variable, while a value of '3' indicates a high probability. The spatial datasets used for this analysis and their associated scores are provided in Table 1.

**Table 1. Analysis scores and scoring criteria for each spatial dataset used in the wetland presence GIS model.**

Spatial Dataset	Analysis Score			
	0	1	2	3
NWI Wetlands	Not present			Present
Hydric Soil Classification	Non-hydric	Partially-hydric		Hydric
LiDAR Topographic Depressions	Not present			Present
LiDAR Topographic Wetness Index (wetness probability)	No wetness indicated	< 25%	25 - 50%	> 50%
Landsat Band 5 Wetlands	Not present			Present

#### *Process and Analyze Data*

Each spatial dataset was processed by the GIS analyst as a separate map layer and every pixel in each spatial dataset was assigned an analysis score of '0' to '3' based on the scoring criteria shown in Table 1. The map layers were combined and the analysis scores for each pixel were added together to determine the aggregate potential wetland presence score for each pixel. The range of aggregate scores was then mapped using a color gradient to depict low-to-high probability of wetland presence and that was overlaid on aerial photography to aid the visual assessment of wetland boundaries. These results were then compared against on-the-ground field observations to determine if the GIS wetland potential model would provide sufficiently improved wetland mapping accuracy for BPA. This is discussed in more detail in the next section.

#### **Compare Results of Original Wetland Mapping and GIS Wetland Potential Model**

Test sites 1, 2, 3, and 4 were visited on November 9 and 10, 2011, because these sites had not been visited during the original mapping phase for the project and delineations had not been conducted at these sites. Reconnaissance-level analysis of the test sites was conducted from

public roadways. Within parcels where property access was provided, hydrologic, vegetation, and soil conditions were studied in detail. In all areas, previously mapped wetlands and GIS model output were compared to on-site conditions. The results for each study area are presented below.

### ***Test Area 1: Cowlitz River***

Overall, previously-mapped wetlands that had been mapped via aerial photo interpretation, NWI data and soil type coincided well with ground conditions. On-site wetlands occur in roughly the same pattern as the mapped wetlands, although the actual wetland areas are more extensive than previously mapped. There are small areas where wetlands occur that were not previously mapped (typically in irregular vegetation patches isolated by roadways).

The GIS model output coincided very well with the on-site conditions and identified wetlands in areas (as noted above) that were not detected using only the soil mapping, NWI and aerial photos used during initial mapping. The model's sensitivity to subtle topographic features and flow concentrations makes it an excellent tool in identifying wetlands in most areas.

In one area (a sand and gravel quarry), the model output indicated major topographic depressions as having a high potential for being wetland. In fact, the soils in this area are so coarse and well-drained that wetland conditions do not occur. Integration of soil moisture data from raw LiDAR data could help reduce these anomalous areas.

### ***Test Area 2: Ceweeman River Crossing and Vicinity***

Previously-mapped wetlands coincided well with ground conditions. On-site wetlands occur in roughly the same pattern as the mapped wetlands, with the actual wetland areas slightly more extensive than previously mapped.

The GIS model output coincided very well with the on-site conditions and identified wetlands in areas that were not detected used during initial mapping. The model's sensitivity to subtle topographic features and upslope contributing drainage area makes it an excellent tool in identifying wetlands in most areas.

The model output was limited in its ability to detect *slope* wetlands, especially forested wetlands.

The model output indicated a moderate likelihood of wetlands in some developed residential areas. Overall flat topography and drainage concentration results due to small topographic features in yards may have contributed to this result. Integration of soil moisture data from raw LiDAR data could help reduce these anomalous areas.

### ***Test Site 3: East Fork of Lewis River***

Overall, previously-mapped wetlands coincided well with ground conditions. On-site wetlands occur in roughly the same pattern as the mapped wetlands, with the actual wetland areas more

extensive than previously mapped. One exception to this trend is the extent of wetlands in forested ravines appears to be less than the previously mapped polygons. Rather, these polygons contain 30 to 40 percent wetland areas consisting of *riverine* wetlands, *slope* wetland in the ravines, and wetlands that flow into the ravines from surrounding terraces.

The GIS model output coincided very well with the on-site conditions and identified wetlands in areas that were not detected during initial mapping. The model's sensitivity to subtle topographic features and flow concentrations makes it an excellent tool in identifying wetlands in most areas. It does an excellent job of identifying wetland area in pastures in which subtle topographic features distinguished wetland from non-wetland areas. It also identified wetlands in shallow topographic features on the glacial terraces that are the highest elevations in this area.

The model output was limited in its ability to detect *slope* wetlands, especially forested wetlands. Integration of soil moisture data from raw LiDAR data could help reduce these anomalous areas.

#### ***Test Site 4: Segment 28***

Overall, previously-mapped wetlands coincided well with ground conditions. On-site wetlands occur in roughly the same pattern as the mapped wetlands, with the actual wetland areas more extensive than previously mapped.

The GIS model output coincided very well with the on-site conditions and identified wetlands in areas that were not detected used during initial mapping. The model's sensitivity to subtle topographic features and flow concentrations makes it an excellent tool in identifying wetlands in most areas. It does an excellent job of identifying wetland area in pastures in which subtle topographic features distinguished wetland from non-wetland areas. It also provided accurate information on wetland conditions on a series of valley-floor terraces.

Much of this study area was forested land without property access. Therefore this analysis was restricted to the two valleys that occur in the test site and immediately adjacent areas.

#### ***Test Site 5: Casey Road Substation***

In this area, the model output was reflective of wetland distribution. The overall pattern of modeled wetland potential coincided well with the location of the delineated wetlands. There is some wetland potential noise in the model output in the extensive forested areas. Re-examining these areas with the model recalibrated, both by class breaks, as well as by integrating soil moisture LiDAR data may increase resolution in these areas.

#### ***Test Site 6: Baxter Road Substation***

This area is an excellent example of the challenges in using remote sensing data to identify wetlands, particularly *slope* and *riverine* wetlands with a forested canopy. The model output confirmed the presence of surface flow patterns, but did not highlight the areas previously delineated on the ground.

## **Revisions to Wetland Mapping Based on Model Output**

Following the field ground-truthing of the model output, the model was revised by:

- Calibrating extracted Landsat brightness values to account for geographic variations in the project area
- Overlaying land use data to help refine criteria for identifying topographic depressions that are truly wetlands

The model was then run for the entire project area that was covered by the LiDAR mapping. Using this model output, the previously mapped wetlands were re-evaluated throughout the project study area.

Within the portion of the study area for which LiDAR data was collected (and therefore where the wetland model was run), wetland boundaries were refined to more closely match anticipated ground conditions, based on the model output and understanding of the model's strengths and limitations, based on the field verification. The high-resolution aerial photos (collected within the LiDAR data area) were also used to identify features that would indicate wetland boundaries (vegetation patterns, evidence of surface water, etc.). These revised wetland boundaries were then extrapolated to cover the entire study area (i.e., those areas outside of the LiDAR coverage). The criteria for extrapolation were: vegetation signatures, other evidence resolved on the aerial photos (e.g., surface water), and topographic features that extended from within the LiDAR coverage to the remainder of the study area. Using these criteria, the wetland boundaries throughout the study area were re-evaluated, and refined where appropriate.

## **Evaluate Wetland Functions**

The U.S. Army Corps of Engineers requested an evaluation of wetland functions within the BPA I-5 Corridor Reinforcement Project study area. This assessment was based entirely on existing information sources and not field assessments. To accommodate this approach, *The Washington State Rating System for Western Washington* (Hruby 2004) was used as a foundation that was modified for this assessment. This approach (Hruby 2004) is commonly referred to in Washington as “the state rating system” and is the established method for evaluating wetland functions in Washington State. A copy of the state rating system data form is included at the end of this memorandum (see Attachment A). Modifications to the state rating system methods used for this functional assessment and the results of the functional assessment are discussed below.

## **Determine Wetland Rating Units**

The state rating system requires that the functional assessment be conducted on what are considered “functional units.” This is to create consistency in evaluations by establishing the appropriate limits for evaluation. Otherwise, a “wetland” could theoretically extend from headwaters to tidelands, severely limiting the ability of the state rating system to evaluate

functional processes of different portions of the watershed. As such, a set of wetland functional unit determination criteria are provided in the system. Those relevant to this project are: Wetland units do not extend through culverts or bridges where water surface elevations are different between the two sides. In addition, *riverine* wetland units are broken at waterfalls and major tributary confluences (for the wetlands along the smaller tributary).

## Determine HGM Classification

The initial step in the state rating system is to determine the hydrogeomorphic (HGM) classification of the wetland. The HGM classification system describes wetlands based on their landscape position, water source, and hydrodynamics. The HGM classes relevant to the wetlands in the project study area are: *depressional* (wetlands located in topographic depressions), *riverine* (wetlands whose water source is flooding from adjacent streams), and *slope* (wetlands such as seeps and springs where water flows through the site but is not stored). The other HGM classes in the state rating system (*lacustrine fringe*, *flats*, and *tidal fringe*) do not occur in the study area.

The state rating system also recognizes the common situation in which multiple HGM classes are included in one wetland system (e.g., *slope* wetlands on the hillslopes above a stream join *riverine* wetlands in the floodplain). In these situations, the state rating system establishes a dominant HGM class on which to base the remainder of the evaluation. This is primarily relevant to the project with regards to *slope* wetlands which, in complexes with other HGM classes, is the subordinate HGM class (the other HGM class in the complex is used for evaluation criteria). Given the nature of the wetlands within the four alternatives and access roads, *slope* wetlands abutted other HGM wetland classes in almost every location. Therefore, for the purposes of this evaluation, all *slope* wetlands were assumed to be in complexes with either *depressional* or *riverine* HGM classes, and those classes were used for evaluation criteria, eliminating the need to apply the *slope* wetland evaluation criteria.

The HGM classification of each wetland as either *depressional* or *riverine* was evaluated first by the Herrera GIS analyst to determine the intersection of wetland polygons with streams, as well as reviewing LiDAR features for topographic depressions. Herrera wetland biologists then reviewed the initial HGM classification and confirmed or modified the class based on features evident in aerial photographs and other data sets.

## Assess Wetland Functions

The State's rating system assesses wetland functions using a series of questions related to functional categories including water quality, hydrology, and habitat, and generates a score for each function category based on the wetland's potential and opportunity for providing the function. Herrera wetlands scientists evaluated each question on the state rating form to determine the feasibility of answering the question using available information (including the LiDAR data) and without conducting site visits. Several questions could not be answered without visiting the wetland and were not included on the modified rating form developed for this project. The modified rating form questions and scoring criteria (see Attachment B) includes:

- List of questions from the state rating system for *depressional* and *riverine* wetlands
- Analysis method to answer each question (“automated” GIS process or “manual” review of wetland and datasets visually by wetland scientists), or indication that analysis was not feasible (NF)
- Variable to be assessed
- Datasets used in the evaluation
- Description of the scoring criteria and the scoring associated with each answer

With the HGM class for each wetland established and the modified rating form developed, the functions of each wetland were assessed through automated GIS and manual processes.

### ***Automated GIS Processes***

Seven questions from the rating system were answered using automated methods for riparian (R.1.1, R.1.2, R.3.1), *depressional* (D.1.2), and habitat (H.1.1, H.2.3, H.2.4) (see Attachment B).

R.1.1 evaluates the potential for the wetland to improve water quality based on the presence of topographic depressions in the floodplain that could slow water velocities, sequestering sediment and the pollutants that bind to sediment. LiDAR coverage was used to determine the extent of topographic depressions. The score is based on the percent cover of depressions in the wetland. Since LiDAR data was only available within 400 feet of each alternative centerline, the functional assessment wetland polygons were clipped to the LiDAR extent prior to calculating percentage of area with topographic depression presence.

R.1.2 evaluates the potential of the wetland to improve water quality based on the complexity of woody vegetation in the wetland. This assessment used the project wetland basemap (which is broken into vegetation types: forested, scrub/shrub, etc.). Wetlands with over 66 percent cover of forest or scrub/shrub vegetation received the highest score (8). Wetlands with between 33 and 66 percent cover of forest or scrub/shrub vegetation or over 66 percent emergent vegetation received an intermediate score (6). Wetlands with over 33 percent vegetation cover, but without any of these characteristics received the lowest score (3). There were no wetlands with less than 33 percent vegetation cover in the study area.

R.3.1 evaluates the potential for the wetland to improve hydrology to downstream systems. In order to increase the fidelity of this portion of the assessment, an initial estimate of wetland width compared to stream width was conducted in GIS, followed by a visual review by wetland scientists to confirm or modify this value. The ratio of wetland width expected to flood (perpendicular to the stream) to estimated stream width determines the score (20:1 or more = 9 points; 10-20:1 = 6 points; 5-10:1 = 4 points, 1-5:1 = 2 points; 1:1 or less = 1 point).

D.1.2 evaluates the potential for the wetland to improve water quality based on soil characteristics. Organic soils and fine-textured mineral soils have a large surface area per unit volume and therefore have a large surface for the microbial processes that reduce nutrients and pollutants. As such, wetlands with these soils have a greater capacity to provide these functions. The wetlands were compared to mapped NRCS soil types. Those that occurred within mapped soil types that met the parameters dictated by the state rating system received a score of 4. Those that did not received a score of zero (0).

H.1.1 evaluates vegetation structure. Points are assigned for each Cowardin (1979) vegetation class that is represented in the wetland. Those points are aggregated for each wetland.

H.2.3 evaluates the proximity of Priority Habitats and Species (PHS) as defined by WDFW within 100 meters of the wetland boundary. Mature forests mapped for this project, as well as PHS spatial data sets were used to determine proximity.

H.2.4. evaluates connectivity with other wetlands. Wetlands along riparian corridors were assumed to have good connectivity. These wetlands, and *depressional* wetlands with three or more wetlands within 0.5 mile, received the highest score (5). *Depressional* wetlands with one or two wetlands within 0.5 mile scored 2 points. No wetlands within 0.5 mile received zero (0) points.

### ***Manual Assessments***

Seven questions from the rating system were answered using manual methods (R.2, R.4, D.2, D.3.3, D.4, H.1.4, H.2.1, and H.2.2) (see Attachment B).

R.2 and D.2 evaluate the opportunity for the wetland to provide water quality improvements. To provide this function, there must be pollution, stormwater and/or sediment sources from an upgradient origin or adjacent source. If land uses that could generate these inputs were determined to be present in a location that could convey these materials into the wetland, then it was assumed that the wetland had the opportunity to provide a water quality improvement function. Having this opportunity doubles the score assigned to the wetland for water quality improvement potential (see questions R.1.2 and D.1.2 above).

D.3.3 evaluates the potential for the wetland to provide hydrologic functions based on the relative size of the wetland compared to its upstream watershed. The watershed extents were estimated based on topographic features and roughly measured to place the watershed/wetland/ratio into one of these categories: less than 10:1 (5 points); between 10:1 and 100:1 (3 points); and 100:1 or greater (zero (0) points).

R.4 and D.4 evaluate the opportunity for the wetland to provide hydrologic (flood attenuation and groundwater recharge) functions. Having this opportunity doubles the score assigned to the wetland for hydrologic potential (see questions R.3.1 and D.3.3 above). To provide this function in *riverine* wetlands, there must be human development or natural resources downstream that could be affected by flooding or erosion. To provide this function in *depressional* wetlands there

cannot be any flood attenuation structures (e.g., dams operated for flood control) within 2,500 feet downstream.

H.1.4 evaluates the complexity of the habitat by assessing the interspersion of different vegetation types as well and vegetation with water and gravel bar features. The scale was simplified to provide two levels of habitat complexity: “high” and “low”. Wetlands were considered highly complex (score of 3) if they met any of the following criteria: Forested (an understory was assumed), Riparian (based on typical riparian configurations), or composed of multiple vegetation (Cowardin 1979) classes. Typical wetlands that scored “low” were wetlands in fields and other structurally simple vegetation types (score of 1).

H.2.1 evaluates the condition of the buffer surrounding the wetland. The buffer evaluation area is 100 meters from the wetland boundary. If the vegetation within 95 percent of the buffer was considered intact and unlikely to receive daily human visits (no roads, except old logging spurs; no golf courses, farms, houses, etc.), then the wetland received the highest possible score (5). If there was minimal intact buffer (perimeter of the wetland largely developed, or surrounded by roads), the wetland received the minimum score (zero [0]). Intermediate buffer conditions received a score of 2.

H.2.2 evaluates wildlife passage corridors between the wetland and relatively large patches (greater than 25 acres) of vegetation. Aerial photos were reviewed to determine if corridors greater than 50 feet wide, with over 30 percent vegetation cover, connected the wetland to the large vegetation patches. If a corridor exists, a score of 4 was assigned. If not, the wetland received a score of zero (0).

## Score Compilation and Ranking

Wetland function scores were calculated for each wetland (see Attachment C). The maximum potential wetland function value was calculated for both *riverine* and *depressional* wetlands. Functional scores derived for each wetland were divided by the maximum potential functional score for the HGM type of the wetland. This value represents the proportion of the maximum possible function provided by each individual wetland. This process also normalizes the results from the two HGM types, allowing for a direct comparison of functional impacts, regardless of HGM type. The functional value, multiplied by impact acreage, provides an estimate of the wetland functional loss that would result from the proposed actions.

The overall trends that resulted from this analysis include:

- Wetlands in less-developed forested areas tended to have higher habitat functions, as a result of more intact buffers and connected wildlife corridors.
- Wetlands in less-developed forested areas that were located in the upper portions of the watersheds in some cases provided lower levels of water quality improvements, based on lack of opportunity if the contributing watershed was roadless.

- Wetlands in developed areas tended to have lower habitat functions due to compromised buffers and lack of connected wildlife corridors.
- Wetlands in pastures and other simplified plant communities tended to have lower water quality, hydrologic, and habitat functions due to the lack of complex vegetation that filters water, reduces floodwater velocities, and provide varied habitat niches.

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## **ATTACHMENT A**

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### **Wetland Function Rating Form Western Washington**



Wetland name or number \_\_\_\_\_

## **WETLAND RATING FORM – WESTERN WASHINGTON**

Version 2 - Updated July 2006 to increase accuracy and reproducibility among users  
Updated Oct 2008 with the new WDFW definitions for priority habitats

Name of wetland (if known): \_\_\_\_\_ Date of site visit: \_\_\_\_\_

Rated by \_\_\_\_\_ Trained by Ecology? Yes    No    Date of training \_\_\_\_\_

SEC:    TWNSHP:    RNGE:    Is S/T/R in Appendix D? Yes    No   

**Map of wetland unit: Figure \_\_\_\_\_ Estimated size \_\_\_\_\_**

## **SUMMARY OF RATING**

### **Category based on FUNCTIONS provided by wetland**

**I    II    III    IV**

Category I = Score >=70
Category II = Score 51-69
Category III = Score 30-50
Category IV = Score < 30

Score for Water Quality Functions  
Score for Hydrologic Functions  
Score for Habitat Functions  
**TOTAL score for Functions**


### **Category based on SPECIAL CHARACTERISTICS of wetland**

**I    II    Does not Apply**

**Final Category (choose the “highest” category from above)**

--

### **Summary of basic information about the wetland unit**

Wetland Unit has Special Characteristics	Wetland HGM Class used for Rating
Estuarine	Depressional
Natural Heritage Wetland	Riverine
Bog	Lake-fringe
Mature Forest	Slope
Old Growth Forest	Flats
Coastal Lagoon	Freshwater Tidal
Interdunal	
None of the above	Check if unit has multiple HGM classes present

Wetland name or number \_\_\_\_\_

### Does the wetland unit being rated meet any of the criteria below?

If you answer YES to any of the questions below you will need to protect the wetland according to the regulations regarding the special characteristics found in the wetland.

<b>Check List for Wetlands That May Need Additional Protection (in addition to the protection recommended for its category)</b>	<b>YES</b>	<b>NO</b>
SP1. <i>Has the wetland unit been documented as a habitat for any Federally listed Threatened or Endangered animal or plant species (T/E species)?</i>  For the purposes of this rating system, "documented" means the wetland is on the appropriate state or federal database.		
SP2. <i>Has the wetland unit been documented as habitat for any State listed Threatened or Endangered animal species?</i>  For the purposes of this rating system, "documented" means the wetland is on the appropriate state database. Note: Wetlands with State listed plant species are categorized as Category I Natural Heritage Wetlands (see p. 19 of data form).		
SP3. <i>Does the wetland unit contain individuals of Priority species listed by the WDFW for the state?</i>		
SP4. <i>Does the wetland unit have a local significance in addition to its functions?</i>  For example, the wetland has been identified in the Shoreline Master Program, the Critical Areas Ordinance, or in a local management plan as having special significance.		

To complete the next part of the data sheet you will need to determine the Hydrogeomorphic Class of the wetland being rated.

The hydrogeomorphic classification groups wetlands into those that function in similar ways. This simplifies the questions needed to answer how well the wetland functions. The Hydrogeomorphic Class of a wetland can be determined using the key below. See p. 24 for more detailed instructions on classifying wetlands.

## Classification of Wetland Units in Western Washington

If the hydrologic criteria listed in each question do not apply to the entire unit being rated, you probably have a unit with multiple HGM classes. In this case, identify which hydrologic criteria in questions 1-7 apply, and go to Question 8.

1. Are the water levels in the entire unit usually controlled by tides (i.e. except during floods)?

NO – go to 2                    YES – the wetland class is **Tidal Fringe**

If yes, is the salinity of the water during periods of annual low flow below 0.5 ppt (parts per thousand)? YES – **Freshwater Tidal Fringe**   NO – **Saltwater Tidal Fringe (Estuarine)**

*If your wetland can be classified as a Freshwater Tidal Fringe use the forms for **Riverine** wetlands. If it is Saltwater Tidal Fringe it is rated as an **Estuarine** wetland. Wetlands that were called estuarine in the first and second editions of the rating system are called Salt Water Tidal Fringe in the Hydrogeomorphic Classification. Estuarine wetlands were categorized separately in the earlier editions, and this separation is being kept in this revision. To maintain consistency between editions, the term “Estuarine” wetland is kept. Please note, however, that the characteristics that define Category I and II estuarine wetlands have changed (see p. ).*

2. The entire wetland unit is flat and precipitation is the only source (>90%) of water to it.

Groundwater and surface water runoff are NOT sources of water to the unit.

NO – go to 3                    YES – The wetland class is **Flats**

If your wetland can be classified as a “Flats” wetland, use the form for **Depressional** wetlands.

3. Does the entire wetland unit **meet both** of the following criteria?

The vegetated part of the wetland is on the shores of a body of permanent open water (without any vegetation on the surface) at least 20 acres (8 ha) in size;  
 At least 30% of the open water area is deeper than 6.6 ft (2 m)?

NO – go to 4                    YES – The wetland class is **Lake-fringe (Lacustrine Fringe)**

4. Does the entire wetland unit **meet all** of the following criteria?

The wetland is on a slope (*slope can be very gradual*),  
 The water flows through the wetland in one direction (unidirectional) and usually comes from seeps. It may flow subsurface, as sheetflow, or in a swale without distinct banks.  
 The water leaves the wetland **without being impounded**?  
NOTE: *Surface water does not pond in these type of wetlands except occasionally in very small and shallow depressions or behind hummocks (depressions are usually <3ft diameter and less than 1 foot deep).*

NO - go to 5                    YES – The wetland class is **Slope**

Wetland name or number \_\_\_\_\_

**5. Does the entire wetland unit **meet all** of the following criteria?**

- The unit is in a valley, or stream channel, where it gets inundated by overbank flooding from that stream or river
- The overbank flooding occurs at least once every two years.

*NOTE: The riverine unit can contain depressions that are filled with water when the river is not flooding.*

NO - go to 6    **YES** – The wetland class is **Riverine**

**6. Is the entire wetland unit in a topographic depression in which water ponds, or is saturated to the surface, at some time during the year. *This means that any outlet, if present, is higher than the interior of the wetland.***

NO – go to 7    **YES** – The wetland class is **Depressional**

**7. Is the entire wetland unit located in a very flat area with no obvious depression and no overbank flooding. The unit does not pond surface water more than a few inches. The unit seems to be maintained by high groundwater in the area. The wetland may be ditched, but has no obvious natural outlet.**

NO – go to 8    **YES** – The wetland class is **Depressional**

**8. Your wetland unit seems to be difficult to classify and probably contains several different HGM classes. For example, seeps at the base of a slope may grade into a riverine floodplain, or a small stream within a depressional wetland has a zone of flooding along its sides. GO BACK AND IDENTIFY WHICH OF THE HYDROLOGIC REGIMES DESCRIBED IN QUESTIONS 1-7 APPLY TO DIFFERENT AREAS IN THE UNIT (make a rough sketch to help you decide). Use the following table to identify the appropriate class to use for the rating system if you have several HGM classes present within your wetland. NOTE: Use this table only if the class that is recommended in the second column represents 10% or more of the total area of the wetland unit being rated. If the area of the class listed in column 2 is less than 10% of the unit; classify the wetland using the class that represents more than 90% of the total area.**

<i>HGM Classes within the wetland unit being rated</i>	<i>HGM Class to Use in Rating</i>
Slope + Riverine	Riverine
Slope + Depressional	Depressional
Slope + Lake-fringe	Lake-fringe
Depressional + Riverine along stream within boundary	Depressional
Depressional + Lake-fringe	Depressional
Salt Water Tidal Fringe and any other class of freshwater wetland	Treat as ESTUARINE under wetlands with special characteristics

If you are unable still to determine which of the above criteria apply to your wetland, or if you have more than 2 HGM classes within a wetland boundary, classify the wetland as **Depressional** for the rating.

<b>D Depressional and Flats Wetlands</b>		<b>Points</b> (only 1 score per box)
<b>WATER QUALITY FUNCTIONS</b> - Indicators that the wetland unit functions to improve water quality		
<b>D</b>	<b>D 1. Does the wetland unit have the <u>potential</u> to improve water quality?</b>	(see p.38)
D	D 1.1 Characteristics of surface water flows out of the wetland: Unit is a depression with no surface water leaving it (no outlet) points = 3 Unit has an intermittently flowing, OR highly constricted permanently flowing outlet points = 2 Unit has an unconstricted, or slightly constricted, surface outlet ( <i>permanently flowing</i> ) points = 1 Unit is a "flat" depression (Q. 7 on key), or in the Flats class, with permanent surface outflow <b>and no obvious natural outlet</b> and/or outlet is a man-made ditch points = 1 <i>(If ditch is not permanently flowing treat unit as "intermittently flowing")</i> Provide photo or drawing	<b>Figure</b> _____
D	S 1.2 The soil 2 inches below the surface (or duff layer) is clay or organic ( <i>use NRCS definitions</i> ) YES points = 4 NO points = 0	
D	D 1.3 Characteristics of persistent vegetation (emergent, shrub, and/or forest Cowardin class) Wetland has persistent, ungrazed, vegetation > = 95% of area points = 5 Wetland has persistent, ungrazed, vegetation > = 1/2 of area points = 3 Wetland has persistent, ungrazed vegetation > = 1/10 of area points = 1 Wetland has persistent, ungrazed vegetation <1/10 of area points = 0 Map of Cowardin vegetation classes	<b>Figure</b> _____
D	D1.4 Characteristics of seasonal ponding or inundation. <i>This is the area of the wetland unit that is ponded for at least 2 months, but dries out sometime during the year. Do not count the area that is permanently ponded. Estimate area as the average condition 5 out of 10 yrs.</i> Area seasonally ponded is > ½ total area of wetland points = 4 Area seasonally ponded is > ¼ total area of wetland points = 2 Area seasonally ponded is < ¼ total area of wetland points = 0 Map of Hydroperiods	<b>Figure</b> _____
D	<b>Total for D 1</b>	Add the points in the boxes above
D	<b>D 2. Does the wetland unit have the <u>opportunity</u> to improve water quality?</b> Answer YES if you know or believe there are pollutants in groundwater or surface water coming into the wetland that would otherwise reduce water quality in streams, lakes or groundwater downgradient from the wetland. <i>Note which of the following conditions provide the sources of pollutants. A unit may have pollutants coming from several sources, but any single source would qualify as opportunity.</i> — Grazing in the wetland or within 150 ft — Untreated stormwater discharges to wetland — Tilled fields or orchards within 150 ft of wetland — A stream or culvert discharges into wetland that drains developed areas, residential areas, farmed fields, roads, or clear-cut logging — Residential, urban areas, golf courses are within 150 ft of wetland — Wetland is fed by groundwater high in phosphorus or nitrogen — Other YES multiplier is 2    NO multiplier is 1	(see p. 44) multiplier _____
D	<b>TOTAL - Water Quality Functions</b> Multiply the score from D1 by D2 Add score to table on p. 1	

<b>D Depressional and Flats Wetlands</b>		<b>Points</b> (only 1 score per box)
<b>HYDROLOGIC FUNCTIONS - Indicators that the wetland unit functions to reduce flooding and stream degradation</b>		
<b>D</b>	<b>D 3. Does the wetland unit have the <u>potential</u> to reduce flooding and erosion?</b>	<i>(see p.46)</i>
D	D 3.1 Characteristics of surface water flows out of the wetland unit Unit is a depression with no surface water leaving it (no outlet)      points = 4 Unit has an intermittently flowing, OR highly constricted permanently flowing outlet      points = 2 Unit is a "flat" depression (Q. 7 on key), or in the Flats class, with permanent surface outflow <b>and no obvious natural outlet</b> and/or outlet is a man-made ditch      points = 1 <i>(If ditch is not permanently flowing treat unit as "intermittently flowing")</i> Unit has an unconstricted, or slightly constricted, surface outlet ( <i>permanently flowing</i> )      points = 0	
D	D 3.2 Depth of storage during wet periods <i>Estimate the height of ponding above the bottom of the outlet. For units with no outlet measure from the surface of permanent water or deepest part (if dry).</i> Marks of ponding are 3 ft or more above the surface or bottom of outlet      points = 7 The wetland is a "headwater" wetland"      points = 5 Marks of ponding between 2 ft to < 3 ft from surface or bottom of outlet      points = 5 Marks are at least 0.5 ft to < 2 ft from surface or bottom of outlet      points = 3 Unit is flat (yes to Q. 2 or Q. 7 on key) but has small depressions on the surface that trap water      points = 1 Marks of ponding less than 0.5 ft      points = 0	
D	D 3.3 Contribution of wetland unit to storage in the watershed <i>Estimate the ratio of the area of upstream basin contributing surface water to the wetland to the area of the wetland unit itself.</i> The area of the basin is less than 10 times the area of unit      points = 5 The area of the basin is 10 to 100 times the area of the unit      points = 3 The area of the basin is more than 100 times the area of the unit      points = 0 Entire unit is in the FLATS class      points = 5	
D	<b>Total for D 3</b>	<i>Add the points in the boxes above</i>
D	<b>D 4. Does the wetland unit have the <u>opportunity</u> to reduce flooding and erosion?</b> Answer YES if the unit is in a location in the watershed where the flood storage, or reduction in water velocity, it provides helps protect downstream property and aquatic resources from flooding or excessive and/or erosive flows. Answer NO if the water coming into the wetland is controlled by a structure such as flood gate, tide gate, flap valve, reservoir etc. OR you estimate that more than 90% of the water in the wetland is from groundwater in areas where damaging groundwater flooding does not occur. <i>Note which of the following indicators of opportunity apply.</i> — Wetland is in a headwater of a river or stream that has flooding problems — Wetland drains to a river or stream that has flooding problems — Wetland has no outlet and impounds surface runoff water that might otherwise flow into a river or stream that has flooding problems — Other _____	<i>(see p. 49)</i>
D	<b>YES</b> multiplier is 2 <b>NO</b> multiplier is 1	multiplier _____
D	<b>TOTAL - Hydrologic Functions</b> Multiply the score from D 3 by D 4 <i>Add score to table on p. 1</i>	

Wetland name or number \_\_\_\_\_

R	<b>Riverine and Freshwater Tidal Fringe Wetlands</b> WATER QUALITY FUNCTIONS - Indicators that wetland functions to improve water quality	<b>Points</b> (only 1 score per box)
R	<b>R 1. Does the wetland unit have the <u>potential</u> to improve water quality?</b>	(see p.52)
R	R 1.1 Area of surface depressions within the riverine wetland that can trap sediments during a flooding event:  Depressions cover >3/4 area of wetland Depressions cover > 1/2 area of wetland If depressions > 1/2 of area of unit draw polygons on aerial photo or map Depressions present but cover < 1/2 area of wetland No depressions present	<b>Figure</b> ____
R	R 1.2 Characteristics of the vegetation in the unit (areas with >90% cover at person height):  Trees or shrubs > 2/3 the area of the unit Trees or shrubs > 1/3 area of the unit Ungrazed, herbaceous plants > 2/3 area of unit Ungrazed herbaceous plants > 1/3 area of unit Trees, shrubs, and ungrazed herbaceous < 1/3 area of unit  Aerial photo or map showing polygons of different vegetation types	<b>Figure</b> ____
R	<i>Add the points in the boxes above</i>	
R	<b>R 2. Does the wetland unit have the <u>opportunity</u> to improve water quality?</b>  Answer YES if you know or believe there are pollutants in groundwater or surface water coming into the wetland that would otherwise reduce water quality in streams, lakes or groundwater downgradient from the wetland? <i>Note which of the following conditions provide the sources of pollutants. A unit may have pollutants coming from several sources, but any single source would qualify as opportunity.</i>  — Grazing in the wetland or within 150ft — Untreated stormwater discharges to wetland — Tilled fields or orchards within 150 feet of wetland — A stream or culvert discharges into wetland that drains developed areas, residential areas, farmed fields, roads, or clear-cut logging — Residential, urban areas, golf courses are within 150 ft of wetland — The river or stream linked to the wetland has a contributing basin where human activities have raised levels of sediment, toxic compounds or nutrients in the river water above standards for water quality — Other _____	(see p.53)  multiplier _____
R	YES multiplier is 2      NO multiplier is 1	
R	<b>TOTAL - Water Quality Functions</b> Multiply the score from R 1 by R 2 <i>Add score to table on p. 1</i>	

### Comments

Wetland name or number \_\_\_\_\_

## Comments

Wetland name or number \_\_\_\_\_

L	<b>Lake-fringe Wetlands</b> WATER QUALITY FUNCTIONS - Indicators that the wetland unit functions to improve water quality	Points (only 1 score per box)
L	<b>L 1. Does the wetland unit have the <u>potential</u> to improve water quality?</b>	(see p.59)
L	<p>L 1.1 Average width of vegetation along the lakeshore (<i>use polygons of Cowardin classes</i>):</p> <ul style="list-style-type: none"> <li>Vegetation is more than 33ft (10m) wide points = 6</li> <li>Vegetation is more than 16 (5m) wide and &lt;33ft points = 3</li> <li>Vegetation is more than 6ft (2m) wide and &lt;16 ft points = 1</li> <li>Vegetation is less than 6 ft wide points = 0</li> </ul> <p style="text-align: center;"><b>Map of Cowardin classes with widths marked</b></p>	<b>Figure</b> _____
L	<p>L 1.2 Characteristics of the vegetation in the wetland: <i>choose the appropriate description that results in the highest points, and do not include any open water in your estimate of coverage. The herbaceous plants can be either the dominant form or as an understory in a shrub or forest community. These are not Cowardin classes. Area of Cover is total cover in the unit, but it can be in patches. NOTE: Herbaceous does not include aquatic bed.</i></p> <ul style="list-style-type: none"> <li>Cover of herbaceous plants is &gt;90% of the vegetated area points = 6</li> <li>Cover of herbaceous plants is &gt;2/3 of the vegetated area points = 4</li> <li>Cover of herbaceous plants is &gt;1/3 of the vegetated area points = 3</li> <li>Other vegetation that is not aquatic bed or herbaceous covers &gt; 2/3 unit points = 3</li> <li>Other vegetation that is not aquatic bed in &gt; 1/3 vegetated area points = 1</li> <li>Aquatic bed vegetation and open water cover &gt; 2/3 of the unit points = 0</li> </ul> <p style="text-align: center;"><b>Map with polygons of different vegetation types</b></p>	<b>Figure</b> _____
L	<i>Add the points in the boxes above</i>	
L	<b>L 2. Does the wetland have the <u>opportunity</u> to improve water quality?</b> Answer YES if you know or believe there are pollutants in the lake water, or polluted surface water flowing through the unit to the lake. <i>Note which of the following conditions provide the sources of pollutants. A unit may have pollutants coming from several sources, but any single source would qualify as opportunity.</i>	(see p.61)
	<ul style="list-style-type: none"> <li>— Wetland is along the shores of a lake or reservoir that does not meet water quality standards</li> <li>— Grazing in the wetland or within 150ft</li> <li>— Polluted water discharges to wetland along upland edge</li> <li>— Tilled fields or orchards within 150 feet of wetland</li> <li>— Residential or urban areas are within 150 ft of wetland</li> <li>— Parks with grassy areas that are maintained, ballfields, golf courses (all within 150 ft. of lake shore)</li> <li>— Power boats with gasoline or diesel engines use the lake</li> <li>— Other _____</li> </ul>	multiplier _____
	<b>YES multiplier is 2      NO multiplier is 1</b>	
L	<b>TOTAL - Water Quality Functions</b>	Multiply the score from L1 by L2 <b>Add score to table on p. 1</b>

## Comments

Wetland name or number \_\_\_\_\_

<b>L</b> Lake-fringe Wetlands		<b>Points</b> (only 1 score per box)
HYDROLOGIC FUNCTIONS - Indicators that the wetland unit functions to reduce shoreline erosion		
<b>L</b>	<b>L 3. Does the wetland unit have the <u>potential</u> to reduce shoreline erosion?</b>	(see p.62)
<b>L</b>	L 3 Distance along shore and average width of Cowardin classes along the lakeshore ( <b>do not include aquatic bed</b> ): ( <i>choose the highest scoring description that matches conditions in the wetland</i> )	<b>Figure</b> _____
	>¾ of distance is shrubs or forest at least 33 ft (10m) wide	points = 6
	>¾ of distance is shrubs or forest at least 6 ft. (2 m) wide	points = 4
	>¼ distance is shrubs or forest at least 33 ft (10m) wide	points = 4
	Vegetation is at least 6 ft (2m) wide (any type except aquatic bed)	points = 2
	Vegetation is less than 6 ft (2m) wide (any type except aquatic bed)	points = 0
	Aerial photo or map with Cowardin vegetation classes	
<b>L</b>	<i>Record the points from the box above</i>	
<b>L</b>	<b>L 4. Does the wetland unit have the <u>opportunity</u> to reduce erosion?</b>	(see p.63)
	Are there features along the shore that will be impacted if the shoreline erodes? <i>Note which of the following conditions apply.</i>	
	— There are human structures and activities along the upland edge of the wetland (buildings, fields) that can be damaged by erosion.	
	— There are undisturbed natural resources along the upland edge of the wetland (e.g. mature forests other wetlands) than can be damaged by shoreline erosion	
	— Other _____	multiplier _____
	YES multiplier is 2      NO multiplier is 1	
<b>L</b>	<b>TOTAL - Hydrologic Functions</b> Multiply the score from L 3 by L 4 <i>Add score to table on p. 1</i>	_____

Comments

### Wetland name or number

S	<b>Slope Wetlands</b>	Points (only 1 score per box)
	WATER QUALITY FUNCTIONS - Indicators that the wetland unit functions to improve water quality	
<b>S</b>	<b>S 1. Does the wetland unit have the <u>potential</u> to improve water quality?</b>	(see p.64)
<b>S</b>	S 1.1 Characteristics of average slope of unit: Slope is 1% or less ( <i>a 1% slope has a 1 foot vertical drop in elevation for every 100 ft horizontal distance</i> ) Slope is 1% - 2% Slope is 2% - 5% Slope is greater than 5%	points = 3 points = 2 points = 1 points = 0
<b>S</b>	S 1.2 The soil 2 inches below the surface (or duff layer) is clay or organic ( <i>use NRCS definitions</i> ) YES = 3 points	NO = 0 points
<b>S</b>	S 1.3 Characteristics of the vegetation in the wetland that trap sediments and pollutants: <i>Choose the points appropriate for the description that best fits the vegetation in the wetland. Dense vegetation means you have trouble seeing the soil surface (&gt;75% cover), and uncut means not grazed or mowed and plants are higher than 6 inches.</i> Dense, uncut, herbaceous vegetation > 90% of the wetland area Dense, uncut, herbaceous vegetation > 1/2 of area Dense, woody, vegetation > 1/2 of area Dense, uncut, herbaceous vegetation > 1/4 of area Does not meet any of the criteria above for vegetation	points = 6 points = 3 points = 2 points = 1 points = 0
	Aerial photo or map with vegetation polygons	
<b>S</b>	<b>Total for S 1</b>	<i>Add the points in the boxes above</i>
<b>S</b>	<b>S 2. Does the wetland unit have the <u>opportunity</u> to improve water quality?</b> Answer YES if you know or believe there are pollutants in groundwater or surface water coming into the wetland that would otherwise reduce water quality in streams, lakes or groundwater downgradient from the wetland. <i>Note which of the following conditions provide the sources of pollutants. A unit may have pollutants coming from several sources, but any single source would qualify as opportunity.</i>	(see p.67)
	<ul style="list-style-type: none"> <li>— Grazing in the wetland or within 150ft</li> <li>— Untreated stormwater discharges to wetland</li> <li>— Tilled fields, logging, or orchards within 150 feet of wetland</li> <li>— Residential, urban areas, or golf courses are within 150 ft upslope of wetland</li> <li>— Other _____</li> </ul>	multiplier _____
	YES multiplier is 2    NO multiplier is 1	_____
<b>S</b>	<b>TOTAL - Water Quality Functions</b>	Multiply the score from S1 by S2 <i>Add score to table on p. 1</i>

## Comments

S	<b>Slope Wetlands</b> HYDROLOGIC FUNCTIONS - Indicators that the wetland unit functions to reduce flooding and stream erosion	<b>Points</b> (only 1 score per box)
S	<b>S 3. Does the wetland unit have the <u>potential</u> to reduce flooding and stream erosion?</b>  S 3.1 Characteristics of vegetation that reduce the velocity of surface flows during storms. <i>Choose the points appropriate for the description that best fit conditions in the wetland. (stems of plants should be thick enough (usually &gt; 1/8in), or dense enough, to remain erect during surface flows)</i> Dense, uncut, <b>rigid</b> vegetation covers > 90% of the area of the wetland.      points = 6 Dense, uncut, <b>rigid</b> vegetation > 1/2 area of wetland      points = 3 Dense, uncut, <b>rigid</b> vegetation > 1/4 area      points = 1 More than 1/4 of area is grazed, mowed, tilled or vegetation is not rigid      points = 0	(see p.68)
S	S 3.2 Characteristics of slope wetland that holds back small amounts of flood flows: The slope wetland has small surface depressions that can retain water over at least 10% of its area. YES      points = 2 NO      points = 0	
S	<i>Add the points in the boxes above</i>	
S	<b>S 4. Does the wetland have the <u>opportunity</u> to reduce flooding and erosion?</b> Is the wetland in a landscape position where the reduction in water velocity it provides helps protect downstream property and aquatic resources from flooding or excessive and/or erosive flows? <i>Note which of the following conditions apply.</i> — Wetland has surface runoff that drains to a river or stream that has flooding problems — Other _____  (Answer NO if the major source of water is controlled by a reservoir (e.g. wetland is a seep that is on the downstream side of a dam) YES multiplier is 2    NO multiplier is 1	(see p. 70)  multiplier _____
S	<b>TOTAL - Hydrologic Functions</b> Multiply the score from S 3 by S 4 <i>Add score to table on p. 1</i>	

**Comments**

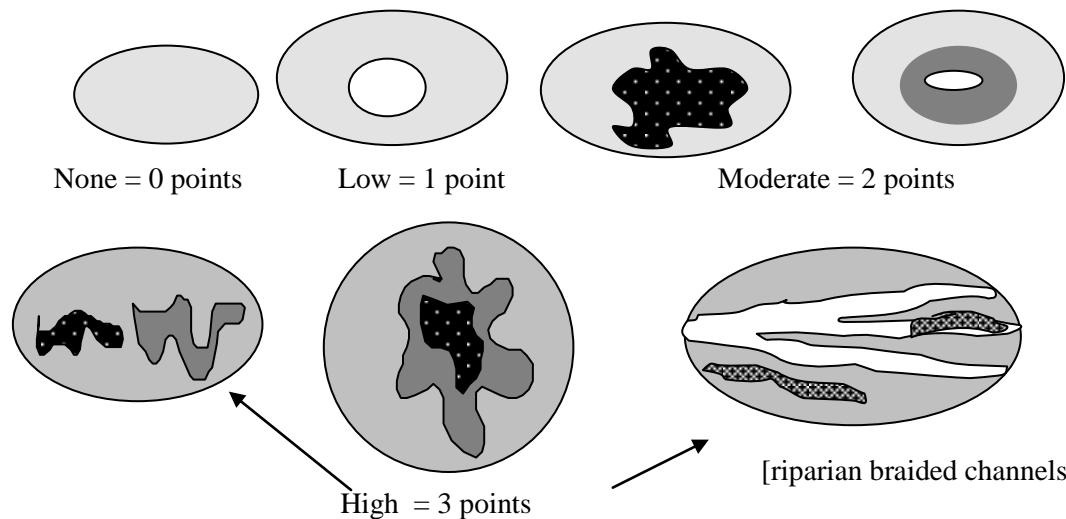
<b><i>These questions apply to wetlands of all HGM classes.</i></b>		<b>Points</b> (only 1 score per box)												
HABITAT FUNCTIONS - Indicators that unit functions to provide important habitat														
<b>H 1. Does the wetland unit have the potential to provide habitat for many species?</b>														
H 1.1 <u>Vegetation structure</u> (see p. 72)		<b>Figure</b> _____												
<p><i>Check the types of vegetation classes present (as defined by Cowardin)- Size threshold for each class is ¼ acre or more than 10% of the area if unit is smaller than 2.5 acres.</i></p> <p><input type="checkbox"/> Aquatic bed  <input type="checkbox"/> Emergent plants  <input type="checkbox"/> Scrub/shrub (areas where shrubs have &gt;30% cover)  <input type="checkbox"/> Forested (areas where trees have &gt;30% cover)</p> <p><i>If the unit has a forested class check if:</i></p> <p><input type="checkbox"/> The forested class has 3 out of 5 strata (canopy, sub-canopy, shrubs, herbaceous, moss/ground-cover) that each cover 20% within the forested polygon</p>														
<p><i>Add the number of vegetation structures that qualify. If you have:</i></p> <table> <tr> <td>Map of Cowardin vegetation classes</td> <td>4 structures or more</td> <td>points = 4</td> </tr> <tr> <td></td> <td>3 structures</td> <td>points = 2</td> </tr> <tr> <td></td> <td>2 structures</td> <td>points = 1</td> </tr> <tr> <td></td> <td>1 structure</td> <td>points = 0</td> </tr> </table>		Map of Cowardin vegetation classes	4 structures or more	points = 4		3 structures	points = 2		2 structures	points = 1		1 structure	points = 0	
Map of Cowardin vegetation classes	4 structures or more	points = 4												
	3 structures	points = 2												
	2 structures	points = 1												
	1 structure	points = 0												
H 1.2. <u>Hydroperiods</u> (see p. 73)		<b>Figure</b> _____												
<p><i>Check the types of water regimes (hydroperiods) present within the wetland. The water regime has to cover more than 10% of the wetland or ¼ acre to count. (see text for descriptions of hydroperiods)</i></p> <p><input type="checkbox"/> Permanently flooded or inundated  <input type="checkbox"/> Seasonally flooded or inundated  <input type="checkbox"/> Occasionally flooded or inundated  <input type="checkbox"/> Saturated only  <input type="checkbox"/> Permanently flowing stream or river in, or adjacent to, the wetland  <input type="checkbox"/> Seasonally flowing stream in, or adjacent to, the wetland</p> <p><b>Lake-fringe wetland = 2 points</b>  <b>Freshwater tidal wetland = 2 points</b></p>														
<p>Map of hydroperiods</p>														
H 1.3. <u>Richness of Plant Species</u> (see p. 75)														
<p>Count the number of plant species in the wetland that cover at least 10 ft<sup>2</sup>. (different patches of the same species can be combined to meet the size threshold)</p> <p><i>You do not have to name the species.</i></p> <p><i>Do not include Eurasian Milfoil, reed canarygrass, purple loosestrife, Canadian Thistle</i></p>														
<p>If you counted:</p> <table> <tr> <td>&gt; 19 species</td> <td>points = 2</td> </tr> <tr> <td>5 - 19 species</td> <td>points = 1</td> </tr> <tr> <td>&lt; 5 species</td> <td>points = 0</td> </tr> </table>		> 19 species	points = 2	5 - 19 species	points = 1	< 5 species	points = 0							
> 19 species	points = 2													
5 - 19 species	points = 1													
< 5 species	points = 0													
<p><i>List species below if you want to:</i></p>														

Total for page \_\_\_\_\_

Wetland name or number \_\_\_\_\_

**H 1.4. Interspersion of habitats (see p. 76)**

Decide from the diagrams below whether interspersion between Cowardin vegetation classes (described in H 1.1), or the classes and unvegetated areas (can include open water or mudflats) is high, medium, low, or none.



NOTE: If you have four or more classes or three vegetation classes and open water the rating is always "high". Use map of Cowardin vegetation classes

**H 1.5. Special Habitat Features: (see p. 77)**

*Check the habitat features that are present in the wetland. The number of checks is the number of points you put into the next column.*

- Large, downed, woody debris within the wetland (>4in. diameter and 6 ft long).
- Standing snags (diameter at the bottom > 4 inches) in the wetland
- Undercut banks are present for at least 6.6 ft (2m) and/or overhanging vegetation extends at least 3.3 ft (1m) over a stream (or ditch) in, or contiguous with the unit, for at least 33 ft (10m)
- Stable steep banks of fine material that might be used by beaver or muskrat for denning (>30degree slope) OR signs of recent beaver activity are present (*cut shrubs or trees that have not yet turned grey/brown*)
- At least 1/4 acre of thin-stemmed persistent vegetation or woody branches are present in areas that are permanently or seasonally inundated. (*structures for egg-laying by amphibians*)
- Invasive plants cover less than 25% of the wetland area in each stratum of plants

*NOTE: The 20% stated in early printings of the manual on page 78 is an error.*

**H 1. TOTAL Score - potential for providing habitat**  
Add the scores from H1.1, H1.2, H1.3, H1.4, H1.5

**Comments**

<b>H 2. Does the wetland unit have the opportunity to provide habitat for many species?</b>		<b>Figure</b> _____
<p><b>H 2.1 Buffers (see p. 80)</b></p> <p><i>Choose the description that best represents condition of buffer of wetland unit. The highest scoring criterion that applies to the wetland is to be used in the rating. See text for definition of "undisturbed."</i></p> <ul style="list-style-type: none"> <li>— 100 m (330ft) of relatively undisturbed vegetated areas, rocky areas, or open water &gt;95% of circumference. No structures are within the undisturbed part of buffer. (relatively undisturbed also means no-grazing, no landscaping, no daily human use) <b>Points = 5</b></li> <li>— 100 m (330 ft) of relatively undisturbed vegetated areas, rocky areas, or open water &gt; 50% circumference. <b>Points = 4</b></li> <li>— 50 m (170ft) of relatively undisturbed vegetated areas, rocky areas, or open water &gt;95% circumference. <b>Points = 4</b></li> <li>— 100 m (330ft) of relatively undisturbed vegetated areas, rocky areas, or open water &gt; 25% circumference, . <b>Points = 3</b></li> <li>— 50 m (170ft) of relatively undisturbed vegetated areas, rocky areas, or open water for &gt; 50% circumference. <b>Points = 3</b></li> </ul> <p><b>If buffer does not meet any of the criteria above</b></p> <ul style="list-style-type: none"> <li>— No paved areas (except paved trails) or buildings within 25 m (80ft) of wetland &gt; 95% circumference. Light to moderate grazing, or lawns are OK. <b>Points = 2</b></li> <li>— No paved areas or buildings within 50m of wetland for &gt;50% circumference. Light to moderate grazing, or lawns are OK. <b>Points = 2</b></li> <li>— Heavy grazing in buffer. <b>Points = 1</b></li> <li>— Vegetated buffers are &lt;2m wide (6.6ft) for more than 95% of the circumference (e.g. tilled fields, paving, basalt bedrock extend to edge of wetland) <b>Points = 0.</b></li> <li>— Buffer does not meet any of the criteria above. <b>Points = 1</b></li> </ul>	Aerial photo showing buffers	
<p><b>H 2.2 Corridors and Connections (see p. 81)</b></p> <p>H 2.2.1 Is the wetland part of a relatively undisturbed and unbroken vegetated corridor (either riparian or upland) that is at least 150 ft wide, has at least 30% cover of shrubs, forest or native undisturbed prairie, that connects to estuaries, other wetlands or undisturbed uplands that are at least 250 acres in size? (<i>dams in riparian corridors, heavily used gravel roads, paved roads, are considered breaks in the corridor</i>).</p> <p>YES = <b>4 points</b> (go to H 2.3)      NO = go to H 2.2.2</p> <p>H 2.2.2 Is the wetland part of a relatively undisturbed and unbroken vegetated corridor (either riparian or upland) that is at least 50ft wide, has at least 30% cover of shrubs or forest, and connects to estuaries, other wetlands or undisturbed uplands that are at least 25 acres in size? <b>OR</b> a <b>Lake-fringe</b> wetland, if it does not have an undisturbed corridor as in the question above?</p> <p>YES = <b>2 points</b> (go to H 2.3)      NO = H 2.2.3</p> <p>H 2.2.3 Is the wetland:</p> <p style="margin-left: 20px;">within 5 mi (8km) of a brackish or salt water estuary <b>OR</b>      within 3 mi of a large field or pasture (&gt;40 acres) <b>OR</b>      within 1 mi of a lake greater than 20 acres?</p> <p>YES = <b>1 point</b>      NO = <b>0 points</b></p>		

Total for page \_\_\_\_\_

**H 2.3 Near or adjacent to other priority habitats listed by WDFW (see new and complete descriptions of WDFW priority habitats, and the counties in which they can be found, in the PHS report <http://wdfw.wa.gov/hab/phslist.htm>)**

Which of the following priority habitats are within 330ft (100m) of the wetland unit? *NOTE: the connections do not have to be relatively undisturbed.*

- Aspen Stands:** Pure or mixed stands of aspen greater than 0.4 ha (1 acre).
- Biodiversity Areas and Corridors:** Areas of habitat that are relatively important to various species of native fish and wildlife (*full descriptions in WDFW PHS report p. 152*).
- Herbaceous Balds:** Variable size patches of grass and forbs on shallow soils over bedrock.
- Old-growth/Mature forests:** (Old-growth west of Cascade crest) Stands of at least 2 tree species, forming a multi-layered canopy with occasional small openings; with at least 20 trees/ha (8 trees/acre) > 81 cm (32 in) dbh or > 200 years of age. (Mature forests) Stands with average diameters exceeding 53 cm (21 in) dbh; crown cover may be less than 100%; crown cover may be less than 100%; decay, decadence, numbers of snags, and quantity of large downed material is generally less than that found in old-growth; 80 - 200 years old west of the Cascade crest.
- Oregon white Oak:** Woodlands Stands of pure oak or oak/conifer associations where canopy coverage of the oak component is important (*full descriptions in WDFW PHS report p. 158*).
- Riparian:** The area adjacent to aquatic systems with flowing water that contains elements of both aquatic and terrestrial ecosystems which mutually influence each other.
- Westside Prairies:** Herbaceous, non-forested plant communities that can either take the form of a dry prairie or a wet prairie (*full descriptions in WDFW PHS report p. 161*).
- Instream:** The combination of physical, biological, and chemical processes and conditions that interact to provide functional life history requirements for instream fish and wildlife resources.
- Nearshore:** Relatively undisturbed nearshore habitats. These include Coastal Nearshore, Open Coast Nearshore, and Puget Sound Nearshore. (*full descriptions of habitats and the definition of relatively undisturbed are in WDFW report: pp. 167-169 and glossary in Appendix A*).
- Caves:** A naturally occurring cavity, recess, void, or system of interconnected passages under the earth in soils, rock, ice, or other geological formations and is large enough to contain a human.
- Cliffs:** Greater than 7.6 m (25 ft) high and occurring below 5000 ft.
- Talus:** Homogenous areas of rock rubble ranging in average size 0.15 - 2.0 m (0.5 - 6.5 ft), composed of basalt, andesite, and/or sedimentary rock, including riprap slides and mine tailings. May be associated with cliffs.
- Snags and Logs:** Trees are considered snags if they are dead or dying and exhibit sufficient decay characteristics to enable cavity excavation/use by wildlife. Priority snags have a diameter at breast height of > 51 cm (20 in) in western Washington and are > 2 m (6.5 ft) in height. Priority logs are > 30 cm (12 in) in diameter at the largest end, and > 6 m (20 ft) long.
- If wetland has **3 or more** priority habitats = **4 points**
- If wetland has **2** priority habitats = **3 points**
- If wetland has **1** priority habitat = **1 point**      No habitats = **0 points**
- Note: All vegetated wetlands are by definition a priority habitat but are not included in this list. Nearby wetlands are addressed in question H 2.4)*

Wetland name or number \_\_\_\_\_

**H 2.4 Wetland Landscape** (*choose the one description of the landscape around the wetland that best fits) (see p. 84)*

There are at least 3 other wetlands within  $\frac{1}{2}$  mile, and the connections between them are relatively undisturbed (light grazing between wetlands OK, as is lake shore with some boating, but connections should NOT be bisected by paved roads, fill, fields, or other development.) points = 5

The wetland is Lake-fringe on a lake with little disturbance and there are 3 other lake-fringe wetlands within  $\frac{1}{2}$  mile points = 5

There are at least 3 other wetlands within  $\frac{1}{2}$  mile, BUT the connections between them are disturbed points = 3

The wetland is Lake-fringe on a lake **with** disturbance and there are 3 other lake-fringe wetland within  $\frac{1}{2}$  mile points = 3

There is at least 1 wetland within  $\frac{1}{2}$  mile. points = 2

There are no wetlands within  $\frac{1}{2}$  mile. points = 0

**H 2. TOTAL Score - opportunity for providing habitat**  
*Add the scores from H2.1, H2.2, H2.3, H2.4*

TOTAL for H 1 from page 14

**Total Score for Habitat Functions** – add the points for H 1, H 2 and record the result on p. 1

## **CATEGORIZATION BASED ON SPECIAL CHARACTERISTICS**

***Please determine if the wetland meets the attributes described below and circle the appropriate answers and Category.***

<b>Wetland Type</b> <i>Check off any criteria that apply to the wetland. Circle the Category when the appropriate criteria are met.</i>	<b>Category</b>
<b>SC 1.0 Estuarine wetlands (see p. 86)</b> Does the wetland unit meet the following criteria for Estuarine wetlands? <ul style="list-style-type: none"> <li>— The dominant water regime is tidal,</li> <li>— Vegetated, and</li> <li>— With a salinity greater than 0.5 ppt.</li> </ul> YES = Go to SC 1.1                          NO _____	
SC 1.1 Is the wetland unit within a National Wildlife Refuge, National Park, National Estuary Reserve, Natural Area Preserve, State Park or Educational, Environmental, or Scientific Reserve designated under WAC 332-30-151? YES = Category I                                  NO go to SC 1.2	<b>Cat. I</b>
SC 1.2 Is the wetland unit at least 1 acre in size and meets at least two of the following three conditions? YES = Category I    NO = Category II <ul style="list-style-type: none"> <li>— The wetland is relatively undisturbed (has no diking, ditching, filling, cultivation, grazing, and has less than 10% cover of non-native plant species. If the non-native <i>Spartina</i> spp. are the only species that cover more than 10% of the wetland, then the wetland should be given a dual rating (I/II). The area of <i>Spartina</i> would be rated a Category II while the relatively undisturbed upper marsh with native species would be a Category I. Do not, however, exclude the area of <i>Spartina</i> in determining the size threshold of 1 acre.</li> <li>— At least <math>\frac{3}{4}</math> of the landward edge of the wetland has a 100 ft buffer of shrub, forest, or un-grazed or un-mowed grassland.</li> <li>— The wetland has at least 2 of the following features: tidal channels, depressions with open water, or contiguous freshwater wetlands.</li> </ul>	<b>Cat. I</b> <b>Cat. II</b> <b>Dual rating</b> <b>I/II</b>

<p><b>SC 2.0 Natural Heritage Wetlands (see p. 87)</b>  Natural Heritage wetlands have been identified by the Washington Natural Heritage Program/DNR as either high quality undisturbed wetlands or wetlands that support state Threatened, Endangered, or Sensitive plant species.</p> <p>SC 2.1 Is the wetland unit being rated in a Section/Township/Range that contains a Natural Heritage wetland? (<i>this question is used to screen out most sites before you need to contact WNHP/DNR</i>)  S/T/R information from Appendix D _____ or accessed from WNHP/DNR web site _____</p> <p>YES _____ – contact WNHP/DNR (see p. 79) and go to SC 2.2      NO _____</p> <p>SC 2.2 Has DNR identified the wetland as a high quality undisturbed wetland or as or as a site with state threatened or endangered plant species?  YES = Category I      NO _____ not a Heritage Wetland</p>	<b>Cat. I</b>
<p><b>SC 3.0 Bogs (see p. 87)</b>  Does the wetland unit (<b>or any part of the unit</b>) meet both the criteria for soils and vegetation in bogs? <i>Use the key below to identify if the wetland is a bog. If you answer yes you will still need to rate the wetland based on its functions.</i></p> <ol style="list-style-type: none"> <li>1. Does the unit have organic soil horizons (i.e. layers of organic soil), either peats or mucks, that compose 16 inches or more of the first 32 inches of the soil profile? (See Appendix B for a field key to identify organic soils)? Yes - go to Q. 3      No - go to Q. 2</li> <li>2. Does the unit have organic soils, either peats or mucks that are less than 16 inches deep over bedrock, or an impermeable hardpan such as clay or volcanic ash, or that are floating on a lake or pond?  Yes - go to Q. 3      No - Is not a bog for purpose of rating</li> <li>3. Does the unit have more than 70% cover of mosses at ground level, AND other plants, if present, consist of the “bog” species listed in Table 3 as a significant component of the vegetation (more than 30% of the total shrub and herbaceous cover consists of species in Table 3)?  Yes – Is a bog for purpose of rating      No - go to Q. 4</li> </ol> <p>NOTE: If you are uncertain about the extent of mosses in the understory you may substitute that criterion by measuring the pH of the water that seeps into a hole dug at least 16” deep. If the pH is less than 5.0 and the “bog” plant species in Table 3 are present, the wetland is a bog.</p> <ol style="list-style-type: none"> <li>1. Is the unit forested (&gt; 30% cover) with sitka spruce, subalpine fir, western red cedar, western hemlock, lodgepole pine, quaking aspen, Englemann’s spruce, or western white pine, WITH any of the species (or combination of species) on the bog species plant list in Table 3 as a significant component of the ground cover (&gt; 30% coverage of the total shrub/herbaceous cover)?</li> <li>2. YES = Category I      No _____ Is not a bog for purpose of rating</li> </ol>	<b>Cat. I</b>

<p><b>SC 4.0 Forested Wetlands (see p. 90)</b></p> <p>Does the wetland unit have at least 1 acre of forest that meet one of these criteria for the Department of Fish and Wildlife's forests as priority habitats? <i>If you answer yes you will still need to rate the wetland based on its functions.</i></p> <ul style="list-style-type: none"> <li>— <b>Old-growth forests:</b> (west of Cascade crest) Stands of at least two tree species, forming a multi-layered canopy with occasional small openings; with at least 8 trees/acre (20 trees/hectare) that are at least 200 years of age OR have a diameter at breast height (dbh) of 32 inches (81 cm) or more.</li> </ul> <p>NOTE: The criterion for dbh is based on measurements for upland forests. Two-hundred year old trees in wetlands will often have a smaller dbh because their growth rates are often slower. The DFW criterion is an “OR” so old-growth forests do not necessarily have to have trees of this diameter.</p> <ul style="list-style-type: none"> <li>— <b>Mature forests:</b> (west of the Cascade Crest) Stands where the largest trees are 80 – 200 years old OR have average diameters (dbh) exceeding 21 inches (53cm); crown cover may be less than 100%; decay, decadence, numbers of snags, and quantity of large downed material is generally less than that found in old-growth.</li> </ul> <p>YES = Category I      NO ____ not a forested wetland with special characteristics</p>	<b>Cat. I</b>
<p><b>SC 5.0 Wetlands in Coastal Lagoons (see p. 91)</b></p> <p>Does the wetland meet all of the following criteria of a wetland in a coastal lagoon?</p> <ul style="list-style-type: none"> <li>— The wetland lies in a depression adjacent to marine waters that is wholly or partially separated from marine waters by sandbanks, gravel banks, shingle, or, less frequently, rocks</li> <li>— The lagoon in which the wetland is located contains surface water that is saline or brackish (&gt; 0.5 ppt) during most of the year in at least a portion of the lagoon (<i>needs to be measured near the bottom</i>)</li> </ul> <p>YES = Go to SC 5.1      NO ____ not a wetland in a coastal lagoon</p>	
<p><b>SC 5.1 Does the wetland meets all of the following three conditions?</b></p> <ul style="list-style-type: none"> <li>— The wetland is relatively undisturbed (has no diking, ditching, filling, cultivation, grazing), and has less than 20% cover of invasive plant species (see list of invasive species on p. 74).</li> <li>— At least ¾ of the landward edge of the wetland has a 100 ft buffer of shrub, forest, or un-grazed or un-mowed grassland.</li> <li>— The wetland is larger than 1/10 acre (4350 square feet)</li> </ul> <p>YES = Category I      NO = Category II</p>	<b>Cat. I</b>  <b>Cat. II</b>

**SC 6.0 Interdunal Wetlands (see p. 93)**

Is the wetland unit west of the 1889 line (also called the Western Boundary of Upland Ownership or WBUE)?

YES - go to SC 6.1                    NO \_\_ not an interdunal wetland for rating

***If you answer yes you will still need to rate the wetland based on its functions.***

In practical terms that means the following geographic areas:

- Long Beach Peninsula- lands west of SR 103
- Grayland-Westport- lands west of SR 105
- Ocean Shores-Copalis- lands west of SR 115 and SR 109

SC 6.1 Is the wetland one acre or larger, or is it in a mosaic of wetlands that is once acre or larger?

YES = Category II                    NO – go to SC 6.2

SC 6.2 Is the unit between 0.1 and 1 acre, or is it in a mosaic of wetlands that is between 0.1 and 1 acre?

YES = Category III

**Cat. II**

**Cat. III**

**Category of wetland based on Special Characteristics**

*Choose the “highest” rating if wetland falls into several categories, and record on p. 1.*

If you answered NO for all types enter “Not Applicable” on p.1



## **ATTACHMENT B**

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# Modified Wetland Function Rating Form Questions and Scoring Criteria I-5 Corridor Reinforcement Project



Table 2. BPA I-5 Corridor Reinforcement Project Wetland Functions Assessment

## Questions and Scoring Criteria

Rating Form Questions		Method (Automated Manual Not Feasible)	Variable	Datasets and Parameters	Scoring Criteria
<b>HGM Class Determination:</b> What is the hydrogeomorphic classification of the wetland?					
	HGM class	M	HGM Class	• WDNR hydrography dataset	<ul style="list-style-type: none"> <li>• <b>Riverine:</b> wetland abuts/intersects stream</li> <li>• <b>Depressional:</b> wetland <u>does not</u> abut/intersect stream, OR wetland <u>does</u> abut/intersect stream and is leveed, OR wetland is situated at the headwaters of a stream</li> <li>• <b>Slope:</b> class not used for this functions analysis. All slope wetland function indicators require site visit to assess.</li> </ul>
<b>Riverine Wetlands - Water Quality Functions:</b> Does the wetland unit have the potential and opportunity to improve water quality?					
Water Quality Potential	R.1.1	A	Topographic depressions	• LiDAR	<ul style="list-style-type: none"> <li>• <b>8 pts:</b> when depressions cover &gt;75% area</li> <li>• <b>4 pts:</b> when depressions cover &gt;50% area</li> <li>• <b>2 pts:</b> when depressions cover 1-50% of area</li> <li>• <b>0 pts:</b> no depressions</li> </ul>
Water Quality Potential	R.1.2	A	Vegetation cover	• Herrera-digitized wetland polygons with Cowardin class attributes	<ul style="list-style-type: none"> <li>• <b>8 pts:</b> PFO or PSS &gt;2/3 area</li> <li>• <b>6 pts:</b> PFO or PSS &gt;1/3 area</li> <li>• <b>6 pts:</b> PEM &gt;2/3 area [assume PEM areas ungrazed]</li> <li>• <b>3 pts:</b> PEM &gt;1/3 area</li> </ul>
Water Quality Opportunity	R.2	M	Development/water quality impairment in contributing basin	<ul style="list-style-type: none"> <li>• Within 150 feet of grazing/fields/orchards/residential/urban areas/golf courses?</li> <li>• Contributing basin – any development/logging/farming/roads upstream within basin?</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Yes:</b> multiplier of 2</li> <li>• <b>No:</b> multiplier of 1 [manually review any wetland that gets a "1"]</li> </ul>
<b>Riverine Wetlands - Hydrologic Functions:</b> Does the wetland unit have the potential and opportunity to reduce flooding and erosion?					
Hydrologic Potential	R.3.1	A + M	Floodplain width relative to stream width (ratio)	• Ratio of average wetland width perpendicular to stream channel width	<ul style="list-style-type: none"> <li>• <b>9 pts:</b> 20+</li> <li>• <b>6 pts:</b> 10-20</li> <li>• <b>4 pts:</b> 5 - &lt;10</li> <li>• <b>2 pts:</b> 1 - &lt;5</li> <li>• <b>1 pt:</b> &lt;1</li> </ul>
Hydrologic Potential	R.3.2	A	Vegetation cover	• Herrera-digitized wetland polygons with Cowardin class attributes	<ul style="list-style-type: none"> <li>• <b>7 pts:</b> PFO or PSS &gt;1/3 area OR PEM &gt;2/3</li> <li>• <b>4 pts:</b> PFO or PSS &gt;1/10 area OR PEM &gt;1/3</li> <li>• <b>0 pts:</b> none of the above</li> </ul>
Hydrologic Opportunity	R.4	M	Opportunity to reduce flooding and erosion	• Visual evidence of presence of downstream development or natural resources that could be impacted by flooding or erosion	<ul style="list-style-type: none"> <li>• <b>Yes:</b> multiplier of 2 [human development or natural resources downstream]</li> <li>• <b>No:</b> multiplier of 1</li> </ul>
<b>Depressional Wetlands - Water Quality Functions:</b> Does the wetland unit have the potential and opportunity to improve water quality?					
Water Quality Potential	D.1.1	NF	Surface water flows	Site visit required	
Water Quality Potential	D.1.2	A	Soils characterstics	• NRCS soils data (mucks/peats or clay loam or finer)	<ul style="list-style-type: none"> <li>• <b>Yes:</b> 4 pts [soil types are mucks, peats, clay loam or finer]</li> <li>• <b>No:</b> 0 pts</li> </ul>
Water Quality Potential	D.1.3	NF	Persistent vegetation	Site visit required	
Water Quality Potential	D.1.4	NF	Seasonal ponding or inundation	Site visit required	
Water Quality Opportunity	D.2	A + M	Development/water quality impairment in contributing basin	<ul style="list-style-type: none"> <li>• Within 150 feet of grazing/fields/orchards/residential/urban areas/golf courses?</li> <li>• Contributing basin – any development/logging/farming/roads upstream within basin?</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Yes:</b> multiplier of 2 [If wetland meets any of the parameters]</li> <li>• <b>No:</b> multiplier of 1 [Biologist should review manually any wetland that gets a "1"]</li> </ul>

**Table 2. BPA I-5 Corridor Reinforcement Project Wetland Functions Assessment**  
**Questions and Scoring Criteria**

Rating Form Questions		Method (Automated Manual Not Feasible)	Variable	Datasets and Parameters	Scoring Criteria
<b>Depressional Wetlands - Hydrologic Functions:</b> Does the wetland unit have the potential and opportunity to reduce flooding and erosion?					
Hydrologic Potential	D.3.1	NF	Surface water flow	Site visit required	
Hydrologic Potential	D.3.2	NF	Storage depth during wet periods	Site visit required	
Hydrologic Potential	D.3.3	M	Contribution to wetland storage	Drainage basin ratio: area of upstream contributing drainage basin to area of wetland unit itself	<ul style="list-style-type: none"> <li>• <b>Ratio less than 10:</b> 5 pts</li> <li>• <b>10 to 100:</b> 3 pts</li> <li>• <b>More than 100:</b> 0 pts</li> </ul>
Hydrologic Opportunity	D.4	M	Opportunity to reduce flooding and erosion	<ul style="list-style-type: none"> <li>• Dam locations</li> <li>• Wetland unit helps protect downstream property and aquatic resources from flooding or excessive erosive flows.</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Yes:</b> multiplier of 2 [dam not immediately downstream]</li> <li>• <b>No:</b> multiplier of 1 [dam immediately downstream]</li> </ul>
<b>Habitat Functions -</b> Does the wetland unit have the potential and opportunity to provide habitat for many species?					
Habitat Potential	H.1.1	A	Vegetation structure	<ul style="list-style-type: none"> <li>• Herrera-digitized wetland polygons with Cowardin class attributes</li> </ul>	<ul style="list-style-type: none"> <li>• <b>PFO present:</b> 2 pts</li> <li>• <b>PSS present:</b> 1 pt</li> <li>• <b>PEM present:</b> 1 pt</li> <li>• <b>PAB present:</b> 1 pt</li> </ul> <p>*sum the above for a given wetland unit (maximum score = 4 pts)</p>
Habitat Potential	H.1.2	NF	Hydroperiods	Site visit required	
Habitat Potential	H.1.3	NF	Plant species richness	Site visit required	
Habitat Potential	H.1.4	M	Interspersion of habitats	<ul style="list-style-type: none"> <li>• Visual assessment by biologist</li> </ul>	<ul style="list-style-type: none"> <li>• <b>High:</b> 3 pts</li> <li>• <b>Low:</b> 1 pt</li> </ul>
Habitat Potential	H.1.5	NF	Special habitat features	Site visit required	
Habitat Opportunity	H.2.1	M	Buffers	<ul style="list-style-type: none"> <li>• Visual assessment by biologist</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Buffer intact:</b> 5 pts</li> <li>• <b>Buffer compromised:</b> 2 pts</li> <li>• <b>Buffer highly altered:</b> 0 pts</li> </ul>
Habitat Opportunity	H.2.2	M	Corridors and Connections	<ul style="list-style-type: none"> <li>• Visual assessment by biologist</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Corridor present:</b> 4 pts</li> <li>• <b>Corridor not present:</b> 0 pts</li> </ul>
Habitat Opportunity	H.2.3	A	Proximity to priority habitats	<ul style="list-style-type: none"> <li>• WDFW PHS data</li> <li>• Herrera-digitized polygons for riverine wetlands, mature forest, and oak woodland</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Riverine wetland:</b> PHS polygon within 100m = 4 pts</li> <li>• <b>Depressional wetland:</b> PHS polygon within 100m, tally number up to 4 points</li> </ul>
Habitat Opportunity	H.2.4	A	Wetland landscape	<ul style="list-style-type: none"> <li>• WDNR hydrography layer</li> <li>• Herrera-digitized wetland polygons</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Wetland connects to stream:</b> 5 pts</li> </ul> <p>If wetland is <u>not</u> connected to stream, then:</p> <ul style="list-style-type: none"> <li>• <b>3+ other wetlands within ½ mile of rated wetland:</b> 5 pts</li> <li>• <b>1 or 2 other wetlands within ½ mile:</b> 2 pts</li> <li>• <b>No other wetlands within ½ mile:</b> 0 pts</li> </ul>

## **ATTACHMENT C**

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### **Wetland Function Scores I-5 Corridor Reinforcement Project**



Analysis methods*		Riverine Wetlands							Depressional Wetlands							Habitat Functions										Total Score		
		Water Quality Functions			Hydrologic Functions				Water Quality Functions				Hydrologic Functions															
Alternative/Option	WETID	HGM class	R.1.1 (A)*	R.1.2 (A)	R.2 (M)	R.3.1 (M)	R.3.2 (A)	R.4 (M)	D.1.1 (NF)	D.1.2 (A)	D.1.3 (NF)	D.1.4 (NF)	D.2 (M)	D.3.1 (NF)	D.3.2 (NF)	D.3.3 (M)	D.4 (M)	H.1.1 (A)	H.1.2 (NF)	H.1.3 (NF)	H.1.4 (M)	H.1.5 (NF)	H.2.1 (M)	H.2.2 (M)	H.2.3 (A)	H.2.4 (A)		
Central Alternative	WET-162	Riverine	2	8	2	4	7	2										3			3		2	4	4	5	63	
Central Alternative	WET-199	Riverine	2	8	2	2	7	2										1			1		2	4	4	5	55	
Central Alternative	WET-200	Riverine	2	8	2	2												2			3		2	4	4	5	44	
Central Alternative	WET-201	Riverine	2	3	2	9	4	2										4			3		2	4	4	5	58	
Central Alternative	WET-202	Depressional							0					2				3	2	2			3	0	4	1	5	21
Central Alternative	WET-204	Riverine	2	8	2	2	7	2											2			3		0	0	4	5	52
Central Alternative	WET-205	Riverine	2	8	2	4	7	2											2			3		5	4	4	5	65
Central Alternative	WET-214	Riverine	2	8	2	2	7	2											2			3		2	4	4	5	58
Central Alternative	WET-216	Riverine	2	8	2	2	7	2											2			3		5	4	4	5	61
Central Alternative	WET-217	Riverine	2	8	2	2	7	2											2			3		5	4	4	5	61
Central Alternative	WET-218	Riverine	2	8	2	2	7	2											2			3		5	4	4	5	61
Central Alternative	WET-219	Riverine	2	8	2	4	7	2											2			3		5	4	4	5	65
Central Alternative	WET-220	Riverine	2	8	2	4	7	2											2			3		2	4	4	5	62
Central Alternative	WET-221	Depressional							0					2				3	2	2			3	2	4	0	5	22
Central Alternative	WET-222	Riverine	2	8	2	2	7	2											2			3		2	4	4	5	58
Central Alternative	WET-223	Depressional							0					2				0	2	2			3	2	4	0	5	16
Central Alternative	WET-224	Riverine	2	8	2	6	7	2											2			3		2	4	4	5	66
Central Alternative	WET-225	Riverine	2	8	2	2	7	2											2			3		2	4	4	5	58
Central Alternative	WET-226	Riverine	2	8	2	2	7	2											2			3		2	4	4	5	58
Central Alternative	WET-227	Riverine	2	8	2	2	7	2											2			3		5	4	4	5	61
Central Alternative	WET-228	Riverine	2	8	2	2	7	2											2			3		2	4	4	5	58
Central Alternative	WET-230	Riverine	2	8	2	2	7	2											2			3		2	4	4	5	58
Central Alternative	WET-231	Riverine	2	8	2	4	7	2											2			3		2	4	4	5	62
Central Alternative	WET-232	Riverine	2	8	2	2	7	2											2			3		2	4	4	5	58
Central Alternative	WET-233	Riverine	2	8	2	6	7	2											2			3		2	4	4	5	66
Central Alternative	WET-234	Riverine	2	8	2	2	7	2											2			3		2	4	4	5	58
Central Alternative	WET-235	Riverine	2	8	2	2	7	2											2			3		2	4	4	5	58
Central Alternative	WET-236	Riverine	2	8	2	4	7	2											2			3		5	4	4	5	65
Central Alternative	WET-237	Depressional							0					2				3	2	2			3	2	4	1	5	23
Central Alternative	WET-238	Riverine	2	8	2	2	7	2											2			3		5	4	4	5	61
Central Alternative	WET-239	Riverine	2	8	2	2	7	2											2			3		5	4	4	5	61
Central Alternative	WET-262	Riverine	2	8	2	4	7	2											2			3		2	4	4	5	62
Central Alternative	WET-263	Riverine	2	8	2	4	7	2											2			3		2	4	4	5	62
Central Alternative	WET-264	Riverine	2	8	2	2	7	2											2			3		5	4	4	5	61
Central Alternative	WET-265	Riverine	2	8	2	2	7	2											2			3		5	4	4	5	61
Central Alternative	WET-266	Riverine	2	8	2	2	7	2											2			3		5	4	4	5	61
Central Alternative	WET-268	Riverine	2	8	2	2	7	2											2			3		5	4	4	5	61
Central Alternative	WET-269	Depressional							0					2				0	2	2			3	2	4	0	5	16
Central Alternative	WET-270	Depressional							0					2				3	2	2			3	5	4	1	5	26
Central Alternative	WET-278	Riverine	2	8	2	2	7	2											2			3		2	4	4	5	58
Central Alternative	WET-280	Riverine	2	8	2	9	7	2											3			3		5	4	4	5	76
Central Alternative	WET-282	Riverine	2	8	2	6	7	2											3			3		0	0	4	5	61
Central Alternative	WET-283	Riverine	2	3	2	6	4	2											4			3		5	4	4	5	55
Central Alternative	WET-285	Riverine	2	6	2	2	7	2											3			3		2	4	4	5	55
Central Alternative	WET-286	Riverine	2	8	2	2	7	2											2			3		5	4	4	5	61
Central Alternative	WET-287	Riverine	2	8	2	2	7	2					</td															







Alternative/Option	WETID	HGM class	Riverine Wetlands							Depressional Wetlands							Habitat Functions										Total Score				
			Water Quality Functions			Hydrologic Functions				Water Quality Functions				Hydrologic Functions																	
			R.1.1 (A) *	R.1.2 (A)	R.2 (M)	R.3.1 (M)	R.3.2 (A)	R.4 (M)	D.1.1 (NF)	D.1.2 (A)	D.1.3 (NF)	D.1.4 (NF)	D.2 (M)	D.3.1 (NF)	D.3.2 (NF)	D.3.3 (M)	D.4 (M)	H.1.1 (A)	H.1.2 (NF)	H.1.3 (NF)	H.1.4 (M)	H.1.5 (NF)	H.2.1 (M)	H.2.2 (M)	H.2.3 (A)	H.2.4 (A)					
Central Alternative	WET-448	Riverine	2	6	2	6	7	2										3			3		2	4	4	5	63				
Central Alternative	WET-450	Riverine	4	8	2	4	7	2										2			3		5	4	4	5	69				
Central Alternative	WET-451	Depressional							0				2			3	2	3			3		2	0	1	5	20				
Central Alternative	WET-452	Riverine	2	8	2	2	7	2										1			3		0	0	4	5	51				
Central Alternative	WET-454	Riverine	2	8	2	6	7	2										2			3		2	4	4	5	66				
Central Alternative	WET-455	Riverine	2	8	2	6	7	2										2			3		2	4	4	5	66				
Central Alternative	WET-456	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Central Alternative	WET-457	Riverine	8	8	2	2	7	2										2			3		2	4	4	5	70				
Central Alternative	WET-458	Depressional							0				2			3	2	2			3		5	4	1	5	26				
Central Alternative	WET-459	Riverine	2	8	2	2	7	2										2			3		5	4	4	5	61				
Central Alternative	WET-460	Depressional							0				2			0	2	2			3		2	4	1	5	17				
Central Alternative	WET-461	Riverine	2	8	2	2	7	2										2			3		5	4	4	5	61				
Central Alternative	WET-464	Depressional							0				2			0	2	3			1		2	4	1	5	16				
Central Alternative	WET-467	Riverine	2	8	2	4	7	2										2			3		2	4	4	5	62				
Central Alternative	WET-468	Riverine	2	8	2	4	7	2										2			3		5	4	4	5	65				
Central Alternative	WET-469	Riverine	2	6	2	6	7	2										4			3		5	4	4	5	67				
Central Alternative	WET-472	Riverine	2	8	2	4	7	2										2			3		2	4	4	5	62				
Central Alternative	WET-475	Riverine	2	8	2	4	7	2										2			3		2	4	4	5	62				
Central Alternative	WET-515	Riverine	2	8	2	2	7	2										3			3		5	4	4	5	62				
Central Alternative	WET-537	Riverine	2	8	2	4	7	2										3			3		2	4	4	5	63				
Central Alternative	WET-561	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Central Alternative	WET-578	Riverine	2	8	2	2	7	2										3			3		2	4	4	5	59				
Central Alternative	WET-595	Riverine	2	8	2	2	7	2										2			3		5	4	4	5	61				
Central Alternative	WET-62	Depressional							0				2			5	2	3			3		2	4	0	5	27				
Central Alternative	WET-63	Depressional							0				2			5	2	3			3		2	4	0	5	27				
Central Alternative	WET-634	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Central Alternative	WET-636	Riverine	2	8	2	2	7	2										2			3		5	4	4	5	61				
Central Alternative	WET-67	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Central Alternative	WET-70	Riverine	2	8	2	4	4	2										3			3		2	4	4	5	57				
Central Alternative	WET-722	Riverine	2	8	1	2	7	2										2			3		2	4	4	5	48				
Central Alternative	WET-736	Riverine	2	8	2	2	7	2										3			3		2	4	4	5	59				
Central Alternative	WET-737	Riverine	2	8	2	4	7	2										2			3		2	4	4	5	62				
Central Alternative	WET-738	Riverine	2	8	2	2	7	2										3			3		2	4	4	5	59				
Central Alternative	WET-742	Depressional							0				2			0	2	2			1		5	4	1	5	18				
Central Alternative	WET-743	Depressional							0				2			0	2	1			1		2	4	1	5	14				
Central Alternative	WET-744	Depressional							0				2			0	2	1			1		2	4	1	5	14				
Central Alternative	WET-748	Depressional							0				2			0	2	2			3		5	4	1	5	20				
Central Alternative	WET-75	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Central Alternative	WET-751	Riverine	2	8	2	1	7	2										4			3		2	4	0	5	54				
Central Alternative	WET-755	Riverine	2	6	2	1	7	2																							



Analysis methods: (A) automated/GIS (M) manual/visual (NF) not feasible, site visit req'd		Riverine Wetlands						Depressional Wetlands								Habitat Functions										Total Score		
		Water Quality Functions			Hydrologic Functions			Water Quality Functions				Hydrologic Functions																
Alternative/Option	WETID	HGM class	R.1.1 (A)*	R.1.2 (A)	R.2 (M)	R.3.1 (M)	R.3.2 (A)	R.4 (M)	D.1.1 (NF)	D.1.2 (A)	D.1.3 (NF)	D.1.4 (NF)	D.2 (M)	D.3.1 (NF)	D.3.2 (NF)	D.3.3 (M)	D.4 (M)	H.1.1 (A)	H.1.2 (NF)	H.1.3 (NF)	H.1.4 (M)	H.1.5 (NF)	H.2.1 (M)	H.2.2 (M)	H.2.3 (A)	H.2.4 (A)		
Central Alternative	WET-812	Depressional							0				2				0	2	2			1		2	0	2	5	12
Central Alternative	WET-813	Riverine	2	6	2	4	7	2											3			3		2	0	4	5	55
Central Alternative	WET-814	Riverine	2	6	2	2	7	2											4			3		2	0	4	5	52
Central Alternative	WET-815	Depressional							0				2				0	2	1			1		0	0	0	5	7
Central Alternative	WET-816	Depressional							0				2				0	2	1			1		0	0	0	5	7
Central Alternative	WET-818	Riverine	2	6	2	1	7	2											4			3		2	4	2	5	52
Central Alternative	WET-819	Riverine	2	8	2	1	7	2											4			3		2	4	4	5	58
Central Alternative	WET-821	Depressional							0				2				0	2	4			3		0	0	0	5	12
Central Alternative	WET-822	Riverine	2	8	2	1	7	2											1			3		2	0	0	5	47
Crossover Alternative	WET-1	Riverine	2	6	2	9	7	2											3			3		2	4	4	5	69
Crossover Alternative	WET-100	Riverine	2	8	2	2	7	2											2			3		2	4	4	5	58
Crossover Alternative	WET-102	Riverine	2	8	2	4	7	2											3			3		2	4	4	5	63
Crossover Alternative	WET-103	Riverine	2	8	2	6	7	2											3			3		2	4	4	5	67
Crossover Alternative	WET-108	Riverine	2	8	2	6	7	2											2			3		2	4	4	5	66
Crossover Alternative	WET-109	Depressional							0				2				5	2	2			3		2	4	0	5	26
Crossover Alternative	WET-110	Riverine	2	8	2	4	7	2											2			3		2	4	4	5	62
Crossover Alternative	WET-111	Riverine	2	8	2	4	7	2											2			3		2	4	4	5	62
Crossover Alternative	WET-112	Riverine	2	6	2	4	7	2											3			3		2	4	4	5	59
Crossover Alternative	WET-113	Riverine	2	8	2	4	7	2											1			3		2	4	4	5	61
Crossover Alternative	WET-114	Riverine	2	8	2	4	7	2											3			3		2	4	4	5	63
Crossover Alternative	WET-115	Riverine	2	8	2	2	7	2											1			1		0	4	4	5	53
Crossover Alternative	WET-116	Riverine	2	8	2	4	7	2											3			3		2	4	4	5	63
Crossover Alternative	WET-117	Riverine	2	8	2	2	7	2											2			3		2	4	4	5	58
Crossover Alternative	WET-118	Riverine	2	6	2	4	7	2											4			3		2	4	4	5	60
Crossover Alternative	WET-119	Riverine	2	8	2	2	7	2											2			1		2	4	4	5	56
Crossover Alternative	WET-121	Riverine	2	8	2	2	7	2											3			3		2	4	4	5	59
Crossover Alternative	WET-122	Riverine	2	8	2	4	7	2											2			3		2	4	4	5	62
Crossover Alternative	WET-124	Riverine	2	8	2	6	7	2											3			3		2	0	4	5	63
Crossover Alternative	WET-143	Riverine	2	6	2	6	7	2											4			1		2	4	4	5	62
Crossover Alternative	WET-162	Riverine	2	8	2	4	7	2											3			3		2	4	4	5	63
Crossover Alternative	WET-163	Riverine	2	8	2	4	7	2											3			3		2	4	4	5	63
Crossover Alternative	WET-165	Riverine	2	8	2	4	7	2											3			3		2	4	4	5	63
Crossover Alternative	WET-166	Riverine	2	8	2	6	7	2											3			3		2	4	4	5	67
Crossover Alternative	WET-168	Depressional							0				2				0	2	1			1		0	0	0	5	7
Crossover Alternative	WET-169	Riverine	2	6	2	6	7	2											1			3		0	4	4	5	59
Crossover Alternative	WET-170	Riverine	2	6	2	6	7	2											1			3		2	4	4	5	61
Crossover Alternative	WET-172	Depressional							0				2				3	2	2			1		0	4	1	5	19
Crossover Alternative	WET-173	Riverine	2	6	2	4	7	2											1			3		2	4	4	5	57
Crossover Alternative	WET-174	Riverine	2	6	2	4	7	2											2			3		2	4	4	5	58
Crossover Alternative	WET-176	Riverine	2	8	2	2	7	2											2			3		2	4	4	5	58
Crossover Alternative	WET-177	Riverine	2	8	2	4	7	2											2			3		2	4	4	5	62
Crossover Alternative	WET-178	Riverine	2	8	2	2	7	2											2			3		2	4	4	5	58
Crossover Alternative	WET-179	Riverine	2	8	2	2	7	2											3			3		2	4	4	5	59
Crossover Alternative	WET-181	Riverine	2	8	2	4	7	2											2			3		2	4	4	5	62
Crossover Alternative	WET-182	Riverine	2	8	2	4	7	2											2			3		2	4	4	5	62
Crossover Alternative	WET-																											







Alternative/Option	WETID	HGM class	Riverine Wetlands							Depressional Wetlands							Habitat Functions										Total Score				
			Water Quality Functions			Hydrologic Functions				Water Quality Functions				Hydrologic Functions																	
			R.1.1 (A) *	R.1.2 (A)	R.2 (M)	R.3.1 (M)	R.3.2 (A)	R.4 (M)	D.1.1 (NF)	D.1.2 (A)	D.1.3 (NF)	D.1.4 (NF)	D.2 (M)	D.3.1 (NF)	D.3.2 (NF)	D.3.3 (M)	D.4 (M)	H.1.1 (A)	H.1.2 (NF)	H.1.3 (NF)	H.1.4 (M)	H.1.5 (NF)	H.2.1 (M)	H.2.2 (M)	H.2.3 (A)	H.2.4 (A)					
Crossover Alternative	WET-616	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Crossover Alternative	WET-617	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Crossover Alternative	WET-619	Riverine	2	6	2	2	7	2										3			3		2	4	4	5	55				
Crossover Alternative	WET-62	Depressional							0									2	3		3		2	4	0	5	27				
Crossover Alternative	WET-620	Riverine	2	8	2	4	7	2										1			3		2	4	4	5	61				
Crossover Alternative	WET-621	Riverine	2	8	2	4	7	2										4			3		2	4	4	5	64				
Crossover Alternative	WET-63	Depressional							0									2	3		3		2	4	0	5	27				
Crossover Alternative	WET-638	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Crossover Alternative	WET-640	Riverine	2	8	2	1	7	2										2			3		2	4	4	5	56				
Crossover Alternative	WET-643	Riverine	0	8	1	2	7	2										2			3		5	4	4	5	49				
Crossover Alternative	WET-645	Riverine	2	6	2	2	7	2										3			3		2	4	4	5	55				
Crossover Alternative	WET-646	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Crossover Alternative	WET-647	Riverine	2	8	2	2	7	2										2			3		5	4	4	5	61				
Crossover Alternative	WET-649	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Crossover Alternative	WET-650	Riverine	2	8	2	2	7	2										2			3		5	4	4	5	61				
Crossover Alternative	WET-653	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Crossover Alternative	WET-654	Riverine	2	8	2	1	7	2										1			3		2	4	4	5	55				
Crossover Alternative	WET-655	Riverine	2	8	2	1	7	2										2			3		2	4	4	5	56				
Crossover Alternative	WET-656	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Crossover Alternative	WET-67	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Crossover Alternative	WET-7	Riverine	2	6	2	6	7	2										3			3		2	4	4	5	63				
Crossover Alternative	WET-70	Riverine	2	8	2	4	4	2										3			3		2	4	4	5	57				
Crossover Alternative	WET-723	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Crossover Alternative	WET-724	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Crossover Alternative	WET-725	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Crossover Alternative	WET-728	Depressional							0									2			5	2	3	1	2	0	5	25			
Crossover Alternative	WET-729	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Crossover Alternative	WET-730	Riverine	2	8	2	2	7	2										2			3		5	4	4	5	61				
Crossover Alternative	WET-75	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Crossover Alternative	WET-751	Riverine	2	8	2	1	7	2										4			3		2	4	0	5	54				
Crossover Alternative	WET-755	Riverine	2	6	2	1	7	2										4			3		2	0	1	5	47				
Crossover Alternative	WET-756	Riverine	2	6	2	2	7	2										4			3		2	0	4	5	52				
Crossover Alternative	WET-757	Depressional							0									2			0	1	0	0	0	5	7				
Crossover Alternative	WET-758	Riverine	2	6	2	1	7	2										3			3		5	0	2	5	50				
Crossover Alternative	WET-761	Riverine	2	8	2	1	7	2										3			3		2	0	4	5	53				
Crossover Alternative	WET-762	Riverine	2	6	2	2	7	2										4			3		2	0	4	5	52				
Crossover Alternative	WET-763	Depressional							0									2			3		0	0	1	5	12				
Crossover Alternative	WET-764	Depressional							0									2			3		0	0	4	5	20				
Crossover Alternative	WET-766	Depressional							0									2			3		0	0	0	5	11				
Crossover Alternative	WET-767	Depressional							0									2		</											































Alternative/Option	WETID	HGM class	Riverine Wetlands							Depressional Wetlands							Habitat Functions										Total Score				
			Water Quality Functions			Hydrologic Functions				Water Quality Functions				Hydrologic Functions																	
			R.1.1 (A) *	R.1.2 (A)	R.2 (M)	R.3.1 (M)	R.3.2 (A)	R.4 (M)	D.1.1 (NF)	D.1.2 (A)	D.1.3 (NF)	D.1.4 (NF)	D.2 (M)	D.3.1 (NF)	D.3.2 (NF)	D.3.3 (M)	D.4 (M)	H.1.1 (A)	H.1.2 (NF)	H.1.3 (NF)	H.1.4 (M)	H.1.5 (NF)	H.2.1 (M)	H.2.2 (M)	H.2.3 (A)	H.2.4 (A)					
Option X1	WET-75	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Option X1	WET-80	Depressional							0				2			0	2	1			1		2	4	0	5	13				
Option X2	WET-205	Riverine	2	8	2	4	7	2										2			3		5	4	4	5	65				
Option X2	WET-214	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Option X2	WET-216	Riverine	2	8	2	2	7	2										2			3		5	4	4	5	61				
Option X2	WET-443	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Option X2	WET-444	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Option X2	WET-445	Riverine	8	8	2	2	7	2										2			3		2	4	4	5	70				
Option X2	WET-446	Riverine	4	8	2	2	7	2										2			3		2	4	4	5	62				
Option X2	WET-448	Riverine	2	6	2	6	7	2										3			3		2	4	4	5	63				
Option X2	WET-483	Riverine	2	8	2	4	7	2										4			3		2	4	4	5	64				
Option X2	WET-495	Depressional							0				2			5	2	1			1		2	4	1	5	24				
Option X2	WET-496	Riverine	2	8	2	6	7	2										4			3		2	4	4	5	68				
Option X2	WET-499	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Option X2	WET-500	Riverine	2	6	2	2	7	2										3			3		2	4	4	5	55				
Option X2	WET-585	Riverine	2	8	2	2	7	2										1			3		2	4	4	5	57				
Option X2	WET-586	Riverine	2	8	2	2	7	2										1			3		2	4	4	5	57				
Option X2	WET-707	Riverine	2	6	2	2	7	2										3			3		2	4	4	5	55				
Option X2	WET-708	Riverine	2	8	2	4	7	2										3			3		2	4	4	5	63				
Option X2	WET-736	Riverine	2	8	2	2	7	2										3			3		2	4	4	5	59				
Option X2	WET-737	Riverine	2	8	2	4	7	2										2			3		2	4	4	5	62				
Option X2	WET-738	Riverine	2	8	2	2	7	2										3			3		2	4	4	5	59				
Option X2	WET-740	Depressional							0				2			0	2	2			3		2	4	1	5	17				
Option X2	WET-742	Depressional							0				2			0	2	2			1		5	4	1	5	18				
Option X2	WET-743	Depressional							0				2			0	2	1			1		2	4	1	5	14				
Option X2	WET-744	Depressional							0				2			0	2	1			1		2	4	1	5	14				
Option X2	WET-748	Depressional							0				2			0	2	2			3		5	4	1	5	20				
Option X3	WET-205	Riverine	2	8	2	4	7	2										2			3		5	4	4	5	65				
Option X3	WET-214	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Option X3	WET-216	Riverine	2	8	2	2	7	2										2			3		5	4	4	5	61				
Option X3	WET-443	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Option X3	WET-444	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
Option X3	WET-445	Riverine	8	8	2	2	7	2										2			3		2	4	4	5	70				
Option X3	WET-446	Riverine	4	8	2	2	7	2										2			3		2	4	4	5	62				
Option X3	WET-448	Riverine	2	6	2	6	7	2										3			3		2	4	4	5	63				
Option X3	WET-483	Riverine	2	8	2	4	7	2										4			3		2	4	4	5	64				
Option X3	WET-496	Riverine	2	8	2	6	7	2										4			3		2	4	4	5	68				
Option X3	WET-498	Depressional							0				2			5	2	2			1		2	4	0	5	24				
Option X3	WET-500	Riverine	2	6	2	2	7	2										3			3		2	4	4	5	55				
Option X3	WET-586	Riverine	2</																												







Alternative/Option	WETID	HGM class	Riverine Wetlands							Depressional Wetlands							Habitat Functions										Total Score				
			Water Quality Functions			Hydrologic Functions				Water Quality Functions				Hydrologic Functions																	
			R.1.1 (A) *	R.1.2 (A)	R.2 (M)	R.3.1 (M)	R.3.2 (A)	R.4 (M)	D.1.1 (NF)	D.1.2 (A)	D.1.3 (NF)	D.1.4 (NF)	D.2 (M)	D.3.1 (NF)	D.3.2 (NF)	D.3.3 (M)	D.4 (M)	H.1.1 (A)	H.1.2 (NF)	H.1.3 (NF)	H.1.4 (M)	H.1.5 (NF)	H.2.1 (M)	H.2.2 (M)	H.2.3 (A)	H.2.4 (A)					
West Alternative	WET-183	Riverine	2	8	2	4	7	2										2			3		2	4	4	5	62				
West Alternative	WET-188	Riverine	2	3	2	9	4	2										4			3		2	4	4	5	58				
West Alternative	WET-189	Depressional							0				2					5	2	2		1		0	0	0	5	18			
West Alternative	WET-190	Riverine	2	6	2	9	7	2										4			3		2	4	4	5	70				
West Alternative	WET-192	Riverine	2	6	2	2	7	2										4			3		2	4	4	5	56				
West Alternative	WET-194	Riverine	2	6	2	9	7	2										4			3		2	4	4	5	70				
West Alternative	WET-197	Riverine	4	8	2	2	7	2										1			3		2	4	4	5	61				
West Alternative	WET-198	Depressional							0				2					3	2	3		1		2	4	2	5	23			
West Alternative	WET-2	Riverine	2	8	2	2	7	2										3			3		2	4	4	5	59				
West Alternative	WET-20	Riverine	2	6	2	2	7	2										3			3		2	4	4	5	55				
West Alternative	WET-21	Riverine	2	8	2	1	7	2										2			3		2	4	4	5	56				
West Alternative	WET-22	Riverine	2	6	2	9	7	2										4			3		2	4	4	5	70				
West Alternative	WET-24	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
West Alternative	WET-242	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
West Alternative	WET-25	Riverine	2	8	2	2	7	2										1			3		2	4	4	5	57				
West Alternative	WET-26	Riverine	2	8	2	2	7	2										3			3		2	4	4	5	59				
West Alternative	WET-27	Riverine	2	8	2	2	7	2										3			3		5	4	4	5	62				
West Alternative	WET-28	Riverine	2	8	1	2	7	2										3			3		5	4	4	5	52				
West Alternative	WET-29	Depressional							0				2					5	2	4		3		0	4	0	5	26			
West Alternative	WET-30	Depressional							4				2					5	2	2		1		2	4	2	5	34			
West Alternative	WET-31	Depressional							0				2					3	2	1		1		0	0	0	5	13			
West Alternative	WET-32	Depressional							0				2					3	2	3		1		0	0	0	5	15			
West Alternative	WET-34	Depressional							0				2					3	2	1		1		0	0	0	5	13			
West Alternative	WET-35	Depressional							0				2					5	2	2		3		0	0	0	5	20			
West Alternative	WET-36	Depressional							0				2					3	2	4		3		0	0	1	5	19			
West Alternative	WET-37	Depressional							0				2					3	2	3		1		0	0	0	5	15			
West Alternative	WET-38	Depressional							0				2					3	2	3		1		2	0	0	5	17			
West Alternative	WET-39	Riverine	2	8	2	2	7	2										4			3		2	4	4	5	60				
West Alternative	WET-4	Riverine	2	8	2	4	7	2										3			3		2	4	4	5	63				
West Alternative	WET-40	Depressional							0				2					3	2	2		3		2	0	1	5	19			
West Alternative	WET-41	Depressional							0				2					5	2	4		3		2	0	0	2	21			
West Alternative	WET-437	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58				
West Alternative	WET-44	Riverine	2	8	2	2	7	2										4			3		2	4	4	5	60				
West Alternative	WET-46	Depressional							0				2					5	2	1		1		0	0	1	2	15			
West Alternative	WET-47	Depressional							0				2					3	2	1		1		2	0	0	5	15			
West Alternative	WET-483	Riverine	2	8	2	4	7	2										4			3		2	4	4	5	64				
West Alternative	WET-501	Riverine	2	8	2	2	7	2										2			3		2	0	4	5	54				
West Alternative	WET-52	Riverine	2	3	2	9	7	2										4			3		2	4	4	5	64				
West Alternative	WET-53	Depressional							0				2					5	2	2		3		0	0	2	5	22			
West Alternative	WET-65	Depressional							0																						



Alternative/Option	WETID	HGM class	Riverine Wetlands							Depressional Wetlands							Habitat Functions								Total Score			
			Water Quality Functions			Hydrologic Functions				Water Quality Functions				Hydrologic Functions														
			R.1.1 (A) *	R.1.2 (A)	R.2 (M)	R.3.1 (M)	R.3.2 (A)	R.4 (M)	D.1.1 (NF)	D.1.2 (A)	D.1.3 (NF)	D.1.4 (NF)	D.2 (M)	D.3.1 (NF)	D.3.2 (NF)	D.3.3 (M)	D.4 (M)	H.1.1 (A)	H.1.2 (NF)	H.1.3 (NF)	H.1.4 (M)	H.1.5 (NF)	H.2.1 (M)	H.2.2 (M)	H.2.3 (A)	H.2.4 (A)		
West Alternative	WET-778	Depressional							0				2			0	2	4			1		2	4	0	5	16	
West Alternative	WET-785	Depressional							0				2			0	2	1			1		0	0	0	5	7	
West Alternative	WET-8	Riverine	2	6	2	6	7	2										1			3		2	4	4	5	61	
West Alternative	WET-811	Depressional							0				2			0	2	1			3		2	0	2	5	13	
West Alternative	WET-812	Depressional							0				2			0	2	2			1		2	0	2	5	12	
West Alternative	WET-813	Riverine	2	6	2	4	7	2										3			3		2	0	4	5	55	
West Alternative	WET-814	Riverine	2	6	2	2	7	2										4			3		2	0	4	5	52	
West Alternative	WET-815	Depressional							0				2			0	2	1			1		0	0	0	5	7	
West Alternative	WET-816	Depressional							0				2			0	2	1			1		0	0	0	5	7	
West Alternative	WET-818	Riverine	2	6	2	1	7	2										4			3		2	4	2	5	52	
West Alternative	WET-819	Riverine	2	8	2	1	7	2										4			3		2	4	4	5	58	
West Alternative	WET-821	Depressional							0				2			0	2	4			3		0	0	0	5	12	
West Alternative	WET-822	Riverine	2	8	2	1	7	2										1			3		2	0	0	5	47	
West Alternative	WET-84	Riverine	2	8	2	4	7	2										2			3		2	4	4	5	62	
West Alternative	WET-87	Riverine	4	8	2	2	7	2										2			3		2	4	4	5	62	
West Alternative	WET-88	Depressional							0				2			5	2	2			3		2	4	0	5	26	
West Alternative	WET-89	Riverine	4	6	2	6	7	2										3			3		2	4	4	5	67	
West Alternative	WET-9	Riverine	2	6	2	2	7	2										2			1		0	0	4	5	46	
West Alternative	WET-90	Riverine	4	6	2	6	7	2										1			1		2	4	4	5	63	
West Alternative	WET-91	Riverine	2	3	2	9	4	2										4			3		2	0	4	5	54	
West Alternative	WET-92	Riverine	2	8	2	4	7	2										1			3		5	4	4	5	64	
West Alternative	WET-93	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58	
West Alternative	WET-94	Depressional							0				2			3	2	2			3		0	0	0	5	16	
West Alternative	WET-96	Depressional							0				2			3	2	1			1		2	4	0	5	19	
West Alternative	WET-97	Riverine	2	8	2	4	7	2										4			3		2	4	4	5	64	
West Alternative	WET-98	Riverine	2	8	2	6	7	2										3			3		2	4	4	5	67	
West Alternative	WET-99	Riverine	2	8	2	2	7	2										2			3		2	4	4	5	58	



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**Appendix M**

**Noxious Weed List**



## Noxious Weed Species that Could Occur or are Known to Occur in Cowlitz, Clark, and Multnomah Counties

Scientific Name	Common Name	Cowlitz County Designation <sup>1</sup>	Clark County Designation <sup>2</sup>	Multnomah County Designation <sup>3,4</sup>
<i>Abutilon theophrasti</i>	velvetleaf	Class A	Class A	Not Listed
<i>Acroptilon repens</i>	Russian knapweed	Class B	Class B*	Not Listed
<i>Aegilops cylindrica</i>	jointed goatgrass	Not Listed	Class C	Class T
<i>Alhagi maurorum</i>	camelthorn	Class B	Class B	Not Listed
<i>Alliaria petiolata</i>	garlic mustard	Class A	Class A* <sup>P</sup>	Class T
<i>Alopecurus myosuroides</i>	blackgrass	Class B	Class B	Not Listed
<i>Amorpha fruticosa</i>	indigobush	Class B*	Class B	Not Listed
<i>Anchusa arvensis</i>	annual bugloss	Class B	Class B	Not Listed
<i>Anchusa officinalis</i>	common bugloss	Class B	Class B	Not Listed
<i>Anthriscus sylvestris</i>	wild chervil	Class B	Class B	Not Listed
<i>Artemisia absinthium</i>	absinth wormwood	Not Listed	Class C	Not Listed
<i>Berteroa incana</i>	Alyssum, hoary	Class B	Class B	Not Listed
<i>Brachypodium sylvaticum</i>	brome, false	Class A <sup>P</sup>	Class A	Class T
<i>Bryonia alba</i>	bryony, white	Class B	Class B	Not Listed
<i>Buddleja davidii</i>	bush, Butterfly	Class B* <sup>P</sup>	Class B*	Class B
<i>Butomus umbellatus</i>	rush, flowering	Class A	Class A	Not Listed
<i>Cabomba caroliniana</i>	fanwort	Class B	Class B	Not Listed
<i>Cardaria draba</i>	hoary cress	Not Listed	Class C	Not Listed
<i>Cardaria pubescens</i>	hairy whitetop	Not Listed	Class C	Class B
<i>Carduus acanthoides</i>	thistle, plumeless	Class B	Class B*	Not Listed
<i>Carduus nutans</i>	thistle, musk	Class B	Class B*	Not Listed
<i>Carduus pycnocephalus</i>	thistle, Italian	Class A	Class A	Not Listed
<i>Carduus tenuiflorus</i>	thistle, slenderflower	Class A <sup>P</sup>	Class A	<b>Class B</b>
<i>Cenchrus longispinus</i>	sandbur, longspine	Class B	Class B	Not Listed
<i>Centaurea biebersteinii</i>	knapweed, spotted	Class B* <sup>P</sup>	Not Listed	Not Listed
<i>Centaurea calcitrapa</i>	starthistle, purple	Class A	Class A <sup>P</sup>	<b>Class A, T</b>
<i>Centaurea diffusa</i>	knapweed, diffuse	Class B* <sup>P</sup>	Class B* <sup>P</sup>	<b>Class B (K)</b>
<i>Centaurea jacea</i>	knapweed, brown	Class B	Class B* <sup>P</sup>	Not Listed
<i>Centaurea jacea x nigra</i>	knapweed, meadow	Class B* <sup>P</sup>	Class B* <sup>P</sup>	Not Listed
<i>Centaurea macrocephala</i>	knapweed, bighead	Class A <sup>P</sup>	Class A <sup>P</sup>	Not Listed
<i>Centaurea nigra</i>	knapweed, black	Class B	Class B* <sup>P</sup>	Not Listed
<i>Centaurea nigrescens</i>	knapweed, Vochin	Class A	Class A <sup>P</sup>	Not Listed
<i>Centaurea solstitialis</i>	starthistle, yellow	Class B	Class B	<b>Class B, T (K)</b>
<i>Centaurea stoebe (biebersteinii)</i>	knapweed, spotted	Class B* <sup>P</sup>	Class B	Class B, T
<i>Chondrilla juncea</i>	skeletonweed, rush	Class B*	Class B	<b>Class B, T (K)</b>

**Noxious Weed Species that Could Occur or are Known to Occur in Cowlitz, Clark, and Multnomah Counties (*continued*)**

<b>Scientific Name</b>	<b>Common Name</b>	<b>Cowlitz County Designation<sup>1</sup></b>	<b>Clark County Designation<sup>2</sup></b>	<b>Multnomah County Designation<sup>3,4</sup></b>
<i>Cirsium arvense</i>	thistle, Canada	Class B* <sup>P</sup>	Class B* <sup>P</sup>	<b>Class B (K)</b>
<i>Cirsium vulgare</i>	thistle, bull	Class C* <sup>P</sup>	Class B* <sup>P</sup>	<b>Class B (K)</b>
<i>Clematis vitalba</i>	old man's beard	Class C*	Class C	<b>Class B (K)</b>
<i>Conium maculatum</i>	poison hemlock	Class B* <sup>P</sup>	Class B	<b>Class B (K)</b>
<i>Convolvulus arvensis</i>	bindweed, field	Class C*	Class C	<b>Class B (K)</b>
<i>Crupina vulgaris</i>	crupina, common	Class A	Class A	Class B
<i>Cuscuta approximata</i>	smoothseed alfalfa dodder	Not Listed	Class C	<b>Class B (K)</b>
<i>Cynoglossum officinale</i>	houndstongue	Class B	Class B	Class B
<i>Cyperus esculentus</i>	nutsedge, yellow	Class B* <sup>P</sup>	Class B	<b>Class B (K)</b>
<i>Cytisus scoparius</i>	scotch broom	Class B* <sup>P</sup>	Class B	<b>Class B (K)</b>
<i>Daphne laureola</i>	spurge laurel	Class B*	Class B	<b>Class B (K)</b>
<i>Daucus carota</i>	carrot, wild	Class B*	Class B	Not Listed
<i>Echium vulgare</i>	blueweed	Class B	Class B	Not Listed
<i>Egeria densa</i>	Brazilian elodea	Class B	Class B	<b>Class B</b>
<i>Epilobium hirsutum</i>	hairy willow-herb	Not Listed	Class C	Not Listed
<i>Euphorbia esula</i>	leafy spurge	Class B	Class B	Class B, T
<i>Euphorbia myrsinites</i>	spurge, myrtle	Class B	Class B	Class B
<i>Euphorbia oblongata</i>	spurge, eggleaf	Class A	Class A	Class A
<i>Foeniculum vulgare</i>	fennel, common	Class B*	Class B	Not Listed
<i>Galega officinalis</i>	goatsrue	Class A	Class A	Class A
<i>Geranium lucidum</i>	geranium, shiny	Class A	Class A <sup>P</sup>	Class B
<i>Geranium robertianum</i>	herb-Robert	Class B*	Class B	Class B
<i>Glyceria maxima</i>	sweetgrass, reed	Class A	Class A	Not Listed
<i>Gypsophila paniculata</i>	babysbreath	Not Listed	Class C	Not Listed
<i>Hedera helix</i>	ivy, English	Class C*	Class C	<b>Class B (K)</b>
<i>Helianthus ciliaris</i>	blueweed, Texas	Class A	Class A	Class A
<i>Hemizonia pungens</i>	spikeweed	Not Listed	Class C	Class B
<i>Heracleum mantegazzianum</i>	hogweed, giant	Class A	Class A	<b>Class A, T (K)</b>
<i>Hieracium atratum</i>	hawkweed, polar	Class B	Class B* <sup>P</sup>	Not Listed
<i>Hieracium aurantiacum</i>	hawkweed, orange	Not Listed	Class B* <sup>P</sup>	<b>Class A, T (K)</b>
<i>Hieracium caespitosum</i> <i>(syn: H. pratense)</i>	Yellow or meadow hawkweed	Class B	Class B* <sup>P</sup>	<b>Class A, T</b>
<i>Hieracium floribundum</i>	hawkweed, yellow devil	Class A	Class A <sup>P</sup>	Class A, T
<i>Hieracium glomeratum</i>	hawkweed, queendevil	Class B	Class B* <sup>P</sup>	Class A
<i>Hieracium lachenalii</i>	hawkweed, common	Not Listed	Class C* <sup>P</sup>	Not Listed

**Noxious Weed Species that Could Occur or are Known to Occur in Cowlitz, Clark, and Multnomah Counties (continued)**

<b>Scientific Name</b>	<b>Common Name</b>	<b>Cowlitz County Designation<sup>1</sup></b>	<b>Clark County Designation<sup>2</sup></b>	<b>Multnomah County Designation<sup>3,4</sup></b>
<i>Hieracium laevigatum</i>	hawkweed, smooth	Class B	Class B* <sup>P</sup>	Not Listed
<i>Hieracium pilosella</i>	hawkweed, mouseear	Class B	Class B* <sup>P</sup>	Class A
<i>Hieracium sabaudum</i>	hawkweed, European	Class A	Class A <sup>P</sup>	Not Listed
<i>Hieracium spp.</i>	hawkweeds, non-native and invasive species not listed elsewhere	Class C*	Class C	Not Listed
<i>Hydrilla verticillata</i>	hydrilla	Class A	Class A	Not Listed
<i>Hyoscyamus niger</i>	black henbane	Not Listed	Class C	Not Listed
<i>Hypericum perforatum</i>	common St. Johnswort	Class C* <sup>P</sup>	Class C	<b>Class B (K)</b>
<i>Hypochaeris radicata</i>	catsear, common	Class B*	Class B	Not Listed
<i>Impatiens glandulifera</i>	helmet, policemen's	Class B*	Class B	<b>Class B (K)</b>
<i>Iris pseudacorus</i>	iris, yellow flag	Class C*	Class C	<b>Class B (K)</b>
<i>Isatis tinctoria</i>	woad, dyers	Class A	Class A	Not Listed
<i>Kochia scoparia</i>	kochia	Class B	Class B	<b>Class B (K)</b>
<i>Lamiastrum galeobdolon</i>	Archangel, yellow	Class C* <sup>P</sup>	Class C	Not Listed
<i>Lepidium latifolium</i>	pepperweed, perennial	Class B*	Class B	<b>Class B, T (K)</b>
<i>Lepidium holosteoides</i>	lepyrodiclis	Class B	Class B	Not Listed
<i>Leucanthemum vulgare</i>	daisy, oxeye	Class B*	Class B	Not Listed
<i>Linaria dalmatica</i> <i>ssp. almatica</i>	toadflax, Dalmatian	Class B* <sup>P</sup>	Class B	<b>Class B, T (K)</b>
<i>Linaria vulgaris</i>	yellow toadflax	Not Listed	Class C	<b>Class B (K)</b>
<i>Ludwigia hexapetala</i>	primrose, water	Class B*	Class B	Not Listed
<i>Ludwigia peploides</i>	primose-willow, floating	Class A	Class A	Not Listed
<i>Lysimachia vulgaris</i>	loosestrife, garden	Class B	Class B	Not Listed
<i>Lythrum salicaria</i>	loosestrife, purple	Class B* <sup>P</sup>	Class B* <sup>P</sup>	<b>Class B (K)</b>
<i>Lythrum virgatum</i>	loosestrife, wand	Class B	Class B	Not Listed
<i>Matricaria perforata</i>	scentless mayweed	Not Listed	Class C	Not Listed
<i>Mirabilis nyctaginea</i>	four o'clock, wild	Class A	Class A	Not Listed
<i>Myriophyllum aquaticum</i>	parrotfeather	Class B*	Class B	<b>Class B (K)</b>
<i>Myriophyllum heterophyllum</i>	variable-leaf milfoil	Class A	Class A	Not Listed
<i>Myriophyllum spicatum</i>	watermilfoil, Eurasian	Class B*	Class B	<b>Class B (K)</b>
<i>Nymphaea odorata</i>	fragrant water lily	Not Listed	Class C	Class B
<i>Nymphoides peltata</i>	floating heart, yellow	Class B	Class B	<b>Class A</b>
<i>Onopordum acanthium</i>	thistle, Scotch	Class B	Class B	Class B

**Noxious Weed Species that Could Occur or are Known to Occur in Cowlitz, Clark, and Multnomah Counties (continued)**

<b>Scientific Name</b>	<b>Common Name</b>	<b>Cowlitz County Designation<sup>1</sup></b>	<b>Clark County Designation<sup>2</sup></b>	<b>Multnomah County Designation<sup>3,4</sup></b>
<i>Phalaris arundinacea</i>	Canarygrass, reed	Class C*	Class C	Not Listed
<i>Phragmites australis</i>	common reed (non-native genotypes)	Class B*	Class B	Class A
<i>Picris hieracioides</i>	hawkweed oxtongue	Class B	Class B	Not Listed
<i>Polygonum bohemicum</i>	knotweed, Bohemian	Class B* <sup>P</sup>	Class B	Not Listed
<i>Polygonum cuspidatum</i>	knotweed, Japanese	Class B* <sup>P</sup>	Class B	<b>Class B (K)</b>
<i>Polygonum polystachyum</i>	knotweed, Himalayan	Class B* <sup>P</sup>	Class B	<b>Class B (K)</b>
<i>Polygonum sachalinense</i>	knotweed, giant	Class B* <sup>P</sup>	Class B	<b>Class B (K)</b>
<i>Potamogeton crispus</i>	curly-leaf pondweed	Not Listed	Class C	Not Listed
<i>Potentilla recta</i>	cinquefoil, sulfur	Class B	Class B	Class B
<i>Pueraria montana</i> var. <i>lobata</i>	kudzu	Class A	Class A	<b>Class A, T (K)</b>
<i>Rorippa austriaca</i>	fieldcress, Austrian	Class B	Class B	Not Listed
<i>Rubus armeniacus</i>	blackberry, Himalayan	Class C*	Class C	<b>Class B (K)</b>
<i>Rubus laciniatus</i>	blackberry, evergreen	Class C*	Class C	Not Listed
<i>Sagittaria graminea</i>	arrowhead, grass-leaved	Class B	Class B	Not Listed
<i>Salvia aethiopis</i>	sage, Mediterranean	Class A	Class A	Class B
<i>Salvia pratensis</i>	clary, meadow	Class A	Class A	Not Listed
<i>Salvia sclarea</i>	sage, clary	Class A	Class A	Not Listed
<i>Schoenoplectus mucronatus</i>	ricefield bulrush	Class A	Class A	Not Listed
<i>Secale cereale</i>	cereal rye	Not Listed	Class C	Not Listed
<i>Senecio jacobaea</i>	ragwort, tansy	Class B* <sup>P</sup>	Class B* <sup>P</sup>	<b>Class B, T (K)</b>
<i>Senecio vulgaris</i>	groundsel, common	Class C*	Class C	Not Listed
<i>Silene latifolia</i> ssp. <i>alba</i>	white cockle	Not Listed	Class C	Not Listed
<i>Silybum marianum</i>	thistle, milk	Class A	Class A	<b>Class B (K)</b>
<i>Solanum elaeagnifolium</i>	nightshade, silverleaf	Class A	Class A	Class A
<i>Solanum rostratum</i>	buffalobur	Class A <sup>P</sup>	Class A	<b>Class B (K)</b>
<i>Soliva sessilis</i>	lawnweed	Class B	Class B	Not Listed
<i>Sonchus arvensis</i> ssp. <i>arvensis</i>	sowthistle, perennial	Class B*	Class B	Not Listed
<i>Sorghum halepense</i>	johnsongrass	Class A	Class A	Class B
<i>Spartina alterniflora</i>	cordgrass, smooth	Class A	Class A	Class T
<i>Spartina anglica</i>	cordgrass, common	Class A	Class A	Class A, T
<i>Spartina densiflora</i>	cordgrass, dense flower	Class A	Class A	Class A, T
<i>Spartina patens</i>	cordgrass, salt meadow	Class A	Class A	Class A, T

## Noxious Weed Species that Could Occur or are Known to Occur in Cowlitz, Clark, and Multnomah Counties (continued)

Scientific Name	Common Name	Cowlitz County Designation <sup>1</sup>	Clark County Designation <sup>2</sup>	Multnomah County Designation <sup>3,4</sup>
<i>Spartium junceum</i>	broom, Spanish	Class A	Class A	Not Listed
<i>Sphaerophysa salsula</i>	swainsonpea	Class B	Class B	Class B
<i>Tamarix ramosissima</i>	saltcedar	Class B*	Class B	Class B, T
<i>Tanacetum vulgare</i>	tansy, Common	Class C <sup>P</sup>	Class C	Not Listed
<i>Thymelaea passerina</i>	flax, spurge	Class A	Class A	Not Listed
<i>Torilis arvensis</i>	hedge parsley	Class B	Not Listed	Not Listed
<i>Tribulus terrestris</i>	puncturevine	Class B	Class B	Class B
<i>Ulex europaeus</i>	gorse	Class B <sup>P</sup>	Class B	<b>Class B, T</b>
<i>Xanthium spinosum</i>	spiny cocklebur	Not Listed	Class C	Class B
<i>Zygophyllum fabago</i>	bean-caper, Syrian	Class A	Class A	Class A

Notes:

\* = designated for control  
P = priority for control

1. Cowlitz County 2010; all Washington Class A weeds require control.
2. Clark County 2010; Lebsack Pers. Comm.; all Washington Class A weeds require control.
3. All Oregon Class A and Class T weeds require control.
4. Multnomah species in **bold** are potentially within 1 mile of the project. Multnomah species with a (**K**) are known to be in the study area. These determinations were made based on observations along roads and other public rights-of-way within 1 mile on either side of the alignment and do not comprise a comprehensive list (Oregon Department of Agriculture 2011, Noxious Weed Mapping in Oregon, on-line map database).

Sources: Washington State Noxious Weed Control Board, 2010, noxious weed information, accessed August 24, 2010 at <http://www.nwcb.wa.gov/index.htm>; Multnomah County Weed Control Program, 2011, Multnomah County Noxious Weed List, accessed July 25, 2011 at <http://www.oregon.gov/ODA/PLANT/WEEDS/multnomah.shtml>.

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## **Appendix N**

### **NEPA Disclosure Forms**



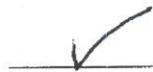
## **NEPA Disclosure Statement for Preparation of an EIS for the Proposed I-5 Corridor Reinforcement Project**

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In accordance with these requirements, the offerer and the proposed subcontractors hereby certify as follows: [check either (a) or (b)].

(a)



Offerer and any proposed subcontractor have no financial interest in the outcome of the project.

(b)



Offerer and any proposed subcontractor have the following financial or other interest in the outcome of the project and hereby agree to divest themselves of such interest prior to the award of the contract.

### **Financial or Other Interests**

1.

2.

3.

Certified by:

Liz A. Mallius

Signature

Liz A. MALLIUS

Name

3/16/11

Date

## **NEPA Disclosure Statement for Preparation of an EIS for the Proposed I-5 Corridor Reinforcement Project**

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### **Financial or Other Interests**

1.

2.

3.

Certified by:

Signature



Name

John L. Fagan

Date

3/30/10

## **NEPA Disclosure Statement for Preparation of an EIS for the Proposed I-5 Corridor Reinforcement Project**

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### **Financial or Other Interests**

1.

2.

3.

Certified by:

Nicole Brannan

Signature

Nicole Brannan

Name

3/23/10

Date

## **NEPA Disclosure Statement for Preparation of an EIS for the Proposed I-5 Corridor Reinforcement Project**

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### **Financial or Other Interests**

1.

2.

3.

Certified by:

Signature

T. DAN BRACKEN

Name

2/11/2010

Date

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### **Financial or Other Interests**

- 1.
- 2.
- 3.

Certified by:

Kathleen Concannon  
Signature  
Kathleen Concannon  
Name  
2/11/10  
Date

## **NEPA Disclosure Statement for Preparation of an EIS for the Proposed I-5 Corridor Reinforcement Project**

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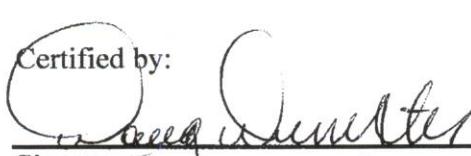
1.  
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Certified by:

Signature

Name

Date



Doug Dunster

March 22, 2010

## NEPA Disclosure Statement for Preparation of an EIS for the Proposed I-5 Corridor Reinforcement Project

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### Financial or Other Interests

1.  
2.  
3.

Certified by:

Frieda J. Christopher  
Signature  
FRIEDA J. CHRISTOPHER, CAD  
Name  
3-10-10  
Date

## **NEPA Disclosure Statement for Preparation of an EIS for the Proposed I-5 Corridor Reinforcement Project**

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### **Financial or Other Interests**

1.  
2.  
3.

Certified by:

Signature

Ernest G. Niemi, Vice President

Name

3-3-10

Date

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### **Financial or Other Interests**

1.

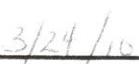
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3.

Certified by:

  
\_\_\_\_\_  
Signature

  
\_\_\_\_\_  
Name

  
\_\_\_\_\_  
Date

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### **Financial or Other Interests**

- 1.
- 2.
- 3.

Certified by:

Signature Nicole R. Zehntbauer  
Name Nicole R. Zehntbauer  
Date 10-13-11

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### **Financial or Other Interests**

- 1.
- 2.
- 3.

Certified by:

Signature

Kara Hempy-Mayer

Name

Kara Hempy-Mayer

Date

10/17/11

## **NEPA Disclosure Statement for Preparation of an EIS for the Proposed I-5 Corridor Reinforcement Project**

CEQ regulations at 40 CFR 1506.5(c), which have been adopted by DOE (10 CFR 1021), require contractors who will prepare an EIS to execute a disclosure specifying that they have no financial or other interest in the outcome of the project. The term "financial interest or other interest in the outcome of the project," for the purposes of this disclosure, is defined in the March 23, 1981 guidance entitled "Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations," 46 FR 18026-180338 at Question 17a and b.

Financial or other interest in the outcome of the project "includes" any financial benefit such as a promise of future construction or design work in the project, as well as indirect benefits the contractor is aware of (e.g., if the project would aid proposals sponsored by the firm's other clients), 46 FR 18026-180338 at 18301.

In accordance with these requirements, the offerer and the proposed subcontractors hereby certify as follows: [check either (a) or (b)].

- (a)       X       Offerer and any proposed subcontractor have no financial interest in the outcome of the project.
- (b) \_\_\_\_\_ Offerer and any proposed subcontractor have the following financial or other interest in the outcome of the project and hereby agree to divest themselves of such interest prior to the award of the contract.

### **Financial or Other Interests**

1.  
2.  
3.

Certified by:

Signature  
William H. Bailey

Name

10/20/2011

Date

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### **Financial or Other Interests**

- 1.
- 2.
- 3.

Certified by:

\_\_\_\_\_  
R. Haynes  
Signature \_\_\_\_\_  
Name \_\_\_\_\_  
Richard W Haynes  
\_\_\_\_\_  
Date \_\_\_\_\_  
10/21/11

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## **Financial or Other Interests**

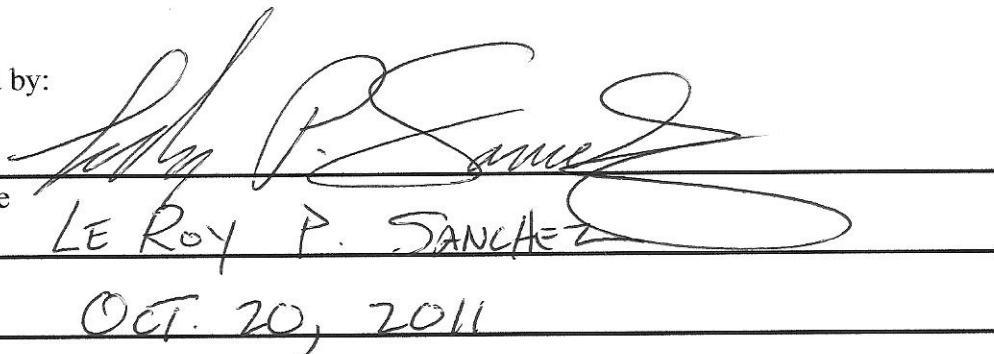
1.  
2.  
3.

Certified by:

Signature

Name

Date



The image shows a handwritten signature in black ink. The signature consists of stylized, flowing letters that appear to read "Le Roy P. Sanchez". This signature is positioned above three horizontal lines, which correspond to the fields for "Signature", "Name", and "Date".

## **NEPA Disclosure Statement for Preparation of an EIS for the Proposed I-5 Corridor Reinforcement Project**

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### **Financial or Other Interests**

1.

2.

3.

Certified by:

Carol Slaughterbeck

Signature

Carol Slaughterbeck

Name

10/24/11

Date

